EFFECTS OF HIGH-INTENSITY FUNCTIONAL TRAINING ON PHYSICAL FITNESS AND JUMPING DIFFICULTY MOVEMENTS AMONG COLLEGE MALE WUSHU ROUTINE ATHLETES IN CHINA

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By

WANG XINZHI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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By

WANG XINZHI

January 2025

Chairman : Professor Soh Kim Geok, PhD
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High-intensity functional training (HIFT) is increasingly recognised as a promising training method. However, its effects on Wushu athletes remain underexplored. This study evaluated the impact of HIFT on physical fitness components (strength, power, endurance, speed, and flexibility) and jumping difficulty movements (Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault) among Chinese male Wushu routine athletes. A cluster-randomised controlled trial (cRCT) was conducted involving 60 male athletes aged 18 - 22 years, randomly assigned to either an experimental group (n = 30) or a control group (n = 30). The experimental group participated in HIFT, while the control group followed a standard Wushu training program consisting of conventional strength and endurance exercises. Both groups trained three times per week for 12 weeks. Data were collected at baseline, 6 weeks (post-test 1), and 12 weeks (post-test 2) using validated physical fitness and technical performance tests. Statistical analysis included analysis of variance (ANOVA) for normally distributed data (e.g., strength, power, endurance, flexibility, and jumping

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difficulty movements) and generalised estimating equations (GEE) for non-normally distributed data (e.g., speed). Results showed significant improvements in physical fitness and jumping difficulty movements for both groups ($p < 0.001$). Notable time and interaction effects (time × group) were observed for strength ($f = 19.099$, $p < 0.001$), power ($f = 32.677$, $p < 0.001$), endurance ($f = 31.325$, $p < 0.001$), speed ($x^2 = 41.899$, $p < 0.001$), flexibility ($f = 28.499$, $p < 0.001$), Flying Kick ($f = 36.394$, $p < 0.001$), Whirlwind Kick ($f = 29.120$, $p < 0.001$), Outward Leg Swing in Flight ($f = 10.423$, $p < 0.001$), and Side Somersault ($f = 26.280$, $p < 0.001$). Improvements were evident after 6 weeks and became more pronounced after 12 weeks. Conclusion: HIFT proved more effective than standard training in enhancing physical fitness (strength, power, endurance, speed, and flexibility) and jump difficulty movements (Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault), with significant improvements observed after a minimum of 6 weeks. These findings highlight the potential of HIFT as an effective training method for Wushu athletes. Future research should explore its application to female athletes, younger age groups, and other technical movements in Wushu.

Keywords: High-intensity functional training, physical fitness, jumping difficulty movement, male Wushu routine athletes

SDG: GOAL 3: Good Health and Well-being, GOAL 4: Quality Education

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN LATIHAN FUNGSIAN BERINTENSITI TINGGI TERHADAP KECERGASAN FIZIKAL DAN PERGERAKAN KESUKARAN MELOMPAT DALAM KALANGAN ATLET RUTIN WUSHU LELAKI KOLEJ DI CHINA

Oleh

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Latihan Fungsional Intensiti Tinggi (HIFT) semakin diiktiraf sebagai kaedah latihan yang menjanjikan. Namun, kesannya terhadap atlet Wushu masih kurang diterokai. Kajian ini menilai kesan HIFT terhadap komponen kecergasan fizikal (kekuatan, kuasa, ketahanan, kelajuan, dan kelenturan) serta pergerakan lompat yang sukar (Tendangan Terbang, Tendangan Puting Beliung, Hayunan Kaki Keluar di Udara, dan Salto Sisi) dalam kalangan atlet rutin Wushu lelaki dari China. Satu percubaan terkawal secara rawak kelompok (cRCT) telah dijalankan melibatkan 60 atlet lelaki berusia 18-22 tahun, yang secara rawak dibahagikan kepada kumpulan eksperimen (n = 30) atau kumpulan kawalan (n = 30). Kumpulan eksperimen mengambil bahagian dalam HIFT, manakala kumpulan kawalan mengikuti program latihan Wushu standard yang terdiri daripada latihan kekuatan dan ketahanan konvensional. Kedua-dua kumpulan menjalani latihan tiga kali seminggu selama 12 minggu. Data dikumpulkan pada garis dasar, 6 minggu (ujian pasca 1), dan 12 minggu (ujian pasca 2) menggunakan ujian kecergasan fizikal dan prestasi teknikal yang disahkan. Analisis

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statistik merangkumi analisis varians (ANOVA) untuk data yang diedarkan secara normal (contohnya, kekuatan, kuasa, ketahanan, kelenturan, dan pergerakan lompat sukar) dan persamaan anggaran umum (GEE) untuk data yang tidak diedarkan secara normal (contohnya, kelajuan). Keputusan menunjukkan peningkatan yang ketara dalam kecergasan fizikal dan pergerakan lompat sukar bagi kedua-dua kumpulan ($p < 0.001$). Kesan masa dan interaksi yang ketara (masa × kumpulan) diperhatikan untuk kekuatan ($f = 19.099$, $p < 0.001$), kuasa ($f = 32.677$, $p < 0.001$), ketahanan ($f = 31.325$, $p < 0.001$), kelajuan ($x^2 = 41.899$, $p < 0.001$), kelenturan ($f = 28.499$, $p < 0.001$), Tendangan Terbang ($f = 36.394$, $p < 0.001$), Tendangan Puting Beliung ($f = 29.120$, $p < 0.001$), Hayunan Kaki Keluar di Udara ($f = 10.423$, $p < 0.001$), dan Salto Sisi ($f = 26.280$, $p < 0.001$). Peningkatan dapat dilihat selepas 6 minggu dan menjadi lebih ketara selepas 12 minggu. Kesimpulan: HIFT terbukti lebih berkesan daripada latihan standard dalam meningkatkan kecergasan fizikal (kekuatan, kuasa, ketahanan, kelajuan, dan kelenturan) dan pergerakan lompat sukar (Tendangan Terbang, Tendangan Puting Beliung, Hayunan Kaki Keluar di Udara, dan Salto Sisi), dengan peningkatan yang ketara diperhatikan selepas minimum 6 minggu. Penemuan ini menyerlahkan potensi HIFT sebagai kaedah latihan yang berkesan untuk atlet Wushu. Penyelidikan masa depan harus menerokai penggunaannya terhadap atlet wanita, kumpulan umur yang lebih muda, dan pergerakan teknikal lain dalam Wushu.

Kata Kunci: Latihan berfungsi-intensiti tinggi, kecergasan fizikal, pergerakan kesukaran melompat, atlet rutin Wushu lelaki

SDG: MATLAMAT 3: Kesehatan dan Kebaikan, MATLAMAT 4: Pendidikan Berkualiti

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

cRCT	Cluster-randomised controlled trial
CG	Control group
EG	Experimental group
GEE	Generalised estimation equation
HIFT	High-intensity functional training
ICC	Intra-cluster correlation coefficient
OLSF	Outward Leg Swing in Flight
WOD	Workout of the day

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CHAPTER 1

INTRODUCTION

This chapter primarily discusses the study background, problem statement, objective, hypothesis, significance, limitations, delimitations, and definitions.

1.1 Background of the Study

Wushu has always existed in Chinese society from ancient times to the present. Influenced by various social and cultural factors, Wushu's nature and attributes have evolved (Lu, 2021). In 1911, Ma Liang's Chinese New Wushu laid the groundwork for competitive Wushu by incorporating teaching methods from Western military gymnastics. This groundwork marked a positive shift from Wushu's Feudalistic Ideologies (Li, 2011). In 1957, Wushu officially became a national competitive sport, signifying its entry onto the world stage (Yang, 2016). Since the emergence of the first set of rules for Wushu competitions in China in 1958, these regulations have been continually refined (Lu, 2021).

According to the rules governing Wushu routine competitions, the scoring system comprises three components: the quality of the movements, the level of execution, and the difficulty of the techniques (Lu, 2021). During the 11th Asian Games in 1990, Wushu was officially included as a competitive event (Lu, 2021). Since 1996, competitive Wushu has steadily grown in its pursuit of Olympic recognition (Han et al., 2021). Among these, competitive Wushu routines have emerged due to the integration and exchange of Eastern and Western sports cultures, characterised by their emphasis on being high in difficulty, aesthetically pleasing, novel, and innovative.

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High, novel, complex, graceful, and stable movements are pivotal for success in Wushu routine competitions. Wushu routines have established systematic scoring criteria that use quantifiable rules to stimulate athletes' competitive spirit, rendering Wushu routine competitions more competitive, standardised, and fair (Xue, 2014). Wushu routine athletes aim to achieve outstanding performance, with their training primarily focused on competition elements defined by Wushu regulations (Qi, 2010). Wushu routines fall into the category of skill-dominant performance sports, demanding rigorous requirements for athletes' physical fitness and skill performance. Athletes must execute dozens of high, novel, complex, graceful and stable movements with high quality and within a specified time frame (Wang, 2011).

Wushu, often referred to as Chinese martial arts, encompasses a wide range of fighting styles, philosophies, and techniques that have evolved over centuries. In the context of this study, Wushu specifically refers to "competitive Wushu," which includes standardised routines characterised by high difficulty, aesthetic value, and innovative techniques, as defined by the Chinese Wushu Association (Su, 2015). Wushu is an intense, full-body activity involving fixed combinations of diverse movements, primarily relying on anaerobic energy systems. Strength, power, speed, endurance, and flexibility are essential physical qualities for exceptional Wushu athletes (Li, 2022). In performing Wushu techniques, athletes predominantly engage in activities that emphasise using major muscle groups, supplemented by the activation of minor muscle groups, to complete a series of intricate technical movements (Montalvo et al., 2022). Wushu routines include running, jumping, kicking, and striking. Demanding athletes are capable of rapid running, swift kicking and striking, and quick turns and transitions (Gao, 2022). Adequate physical fitness constitutes a prerequisite for Wushu routine athletes to achieve commendable athletic performance (Su, 2015). Furthermore, according to the latest Wushu routine competition rules, difficulty movements are divided into four categories: balance, leg techniques, jumps, and falls. The jump technique is the leading factor influencing Wushu routine competition scores and represents the core of Wushu routine movement system innovation (Li, 2022).

For Wushu, having excellent physical fitness is crucial for performing challenging skills and achieving outstanding competition results (Ren et al., 2022). For instance, Strength and Power: The execution of aerial techniques in Wushu, such as the Flying Kick and Whirlwind Kick, demands exceptional lower-body strength and rapid muscle contraction (Zhang & Lu, 2023). Endurance: Wushu competitions typically last 1–2 minutes, requiring elite athletes to possess high levels of cardiovascular endurance to sustain movement fluidity and execution quality (Huang, 2022). Speed: The rapid transitions movements in Wushu necessitate superior speed capabilities (Cai, 2020). Flexibility: Wushu requires extreme body flexibility to perform complex movements such as the Outward Leg Swing in Flight and Side Somersault (Wei, 2015). Performance by Wushu routine athletes in vertical jumps includes metrics like jump height, aerial striking speed, mid-air manoeuvres, and landing stability. Jumping Difficulty: In the Wushu scoring system, jumping techniques contribute significantly to overall performance, making their quality a crucial determinant of competition success (Xu, 2022). Accomplishing these demanding actions significantly relies on the strength of the core muscle groups (strength, endurance, and flexibility) and the athlete’s dynamic balance ability during aerial movements (Li, 2022). In Wushu routine sports, physical fitness and skill performance complement each other. Skill training improves physical fitness, enhancing precision, accuracy, and stability in executing complicated movements (Gao, 2022).

The functional movement status of athletes is pivotal for maximising their technical performance in Wushu competitions (Su, 2015). Actions such as jumping, rotating, evading, and kicking are the most frequently employed movements in Wushu (Gao, 2022). Movement speed, continuity, range, and stability are critical factors in scoring for Wushu routine competitions. If Wushu athletes are restricted in numerous movements due to joint limitations or cannot perform multi-joint movements across various planes, their limited functional mobility will severely affect their performance (Beckham & Harper, 2010; Ratamess, 2021). One study suggests a positive correlation between the severity and frequency of sports-related injuries in martial artists and their performance levels (Jia & Zhang, 2022). The order in which athletes generate force is crucial for the quality of Wushu routine movements. Any stiffness in any part of the sequence can disrupt the coherence of the kinetic chain, leading to errors in routine movements and a reduction in aesthetic appeal (Su, 2015). Vladimir Janda introduced the notion of chain reaction, which describes the human motion chain system as muscles, joints, and nerves (Izraelski, 2012).

Moreover, Peter McGinnis divided human motion into four manifestations according to its dynamic characteristics: leg strength support, symmetrical motion of limbs and trunk, asymmetrical motion of limbs and trunk, and symmetrical and asymmetrical composite motion (McGinnis, 2013). The Best Performance Pyramid Model proposed by Cook accentuates the importance of establishing a robust foundation of physical fitness and functional exercise before concentrating on specific motor skills and tactical strategies. Physical health is fundamental to skill development and improving athletic performance (Sciascia & Cromwell, 2012). Athletes' sports performance may be enhanced with scientific and systematic specific skill training (D'Isanto, 2019).

Unlike other sports, Wushu has unique physical requirements and training patterns, necessitating specialised training programs. High-intensity Functional Training (HIFT) has emerged as a promising training method, with CrossFit, Fran, Cindy, and other HIFT-based workouts gaining popularity in the global fitness community (Brisebois, 2018; Feito, 2018). HIFT is a functional fitness approach with relatively high training intensity in various workout routines, emphasising multi-joint, functional, high-intensity, and full-body movements that combine strength and bodyweight exercises (Feito, 2019; Feito, 2018). It improves muscular strength, power, hypertrophy, and aerobic endurance (Bustos-Viviescas et al., 2022; Kliszczewicz et al, 2018). Furthermore, HIFT can be customised based on specific sports, training modes, and athlete needs (Falk & Kennedy, 2019). Current research suggests that HIFT programs result in similar or lower injury risks than traditional physical training activities (Poston et al., 2016; Tibana et al., 2018), establishing HIFT as a safe strategy.

Many players and trainers have used HIFT to obtain a competitive advantage in their workout schedules. Research reveals that functional multi-joint exercises in HIFT successfully increase overall physical metrics and athletic ability across diverse training populations (Box et al., 2019; Heinrich et al., 2015; Murawska-Cialowicz et al., 2015; Senefeld & Joyner, 2020). Therefore, it is necessary to investigate the impact of HIFT on Wushu athletes to determine its effectiveness in enhancing their physical and jumping difficulty movement. The study focuses on five core physical fitness indicators: strength, power, endurance, speed, and flexibility, all of which play a decisive role in executing Wushu routines. For instance, strength and power are critical for performing aerial techniques such as the Flying Kick, while flexibility and speed influence the fluidity and aesthetic appeal of movements (Chen, 2022; Lu et al., 2021). According to the Wushu routine competition rules, jumping difficulty movements are categorized into four types: balancing, leg techniques, jumping techniques, and falling techniques. This study selected C-level jumping skills including Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault, which hold significant weight in the scoring system. The scoring criteria primarily assess height, mid-air posture, continuity of movement, and landing stability (Chinese Wushu Association, 2021; Lu, 2021).

1.2 Statement of the Problem

Wushu, known as China's national treasure, has reached a relatively mature stage in its development. However, there are several ongoing issues in the current Wushu training process. After 2001, the development of Wushu routines entered a bottleneck phase, lagging in innovative training theories and technical movements (Han et al., 2021). With the continuous evolution of competition regulations, the requirements for high-difficulty movements, such as jumping techniques, in Wushu routine competitions have significantly increased. However, existing training methods often fail to meet these new demands (Huang, 2022; Lu, 2021). Data reveals significant disparities in competitive levels across different regions, with some areas even experiencing a decline in performance. For instance, the Sichuan team has shown a downward trend in results since 2003 (Xu et al., 2022; Huang, 2022). Many elite athletes suffer from insufficient physical fitness during the later stages of competitions, leading to technical errors and negatively impacting their final performance (Saad, 2024).The competitive landscape of Wushu routine athletes exhibits a development trend characterised by "a few strong, many mediocre, and numerous weak" (Fu et al., 2024). The medals in competitive sports events serve as crucial indicators reflecting the competitive strength and reserve talent resources of participating countries and regions. Figure 1.1 displays the gold medal statistics for China's first National Student Wushu Routine Competition in 2023 (Fu et al., 2024). As shown in Figure 1.1, Tianjin Province secured five gold medals, accounting for 11.9% of the gold medals, significantly surpassing other regions in overall strength. Guangdong Province ranks second with four gold medals, representing 9.5%. However, eight teams won one gold medal each. Notably, Hebei Province did not win any gold medals. This highlights the considerable disparity in competitive strength among different regions (Xu et al., 2022).

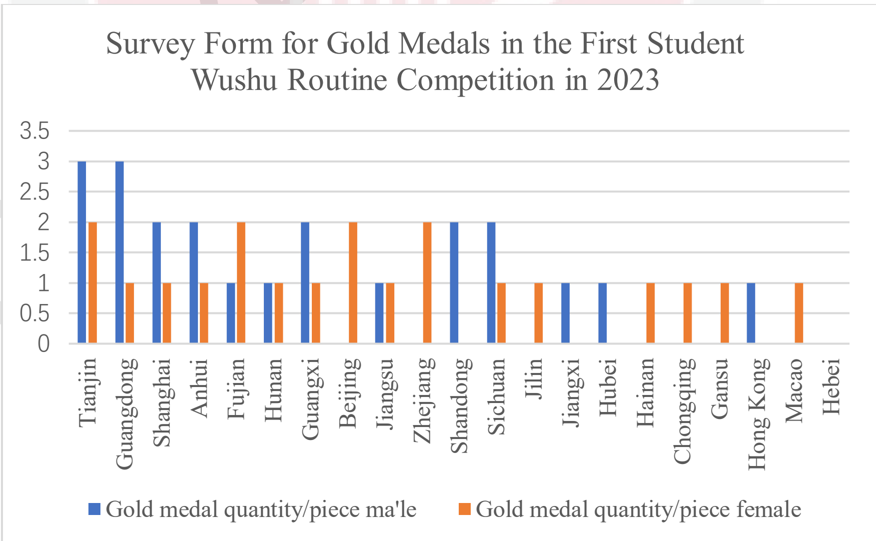

Figure 1.1 : Survey form for Gold Medals in the First Student Wushu Routine Competition 2023

Jumping difficulty movements hold a substantial point value in Wushu routine competitions. Research has found that the main reasons for athletes losing points in jumping difficulty movements in Wushu routine competitions include low jump height, insufficient degrees of rotation in the air, low height of kicking, lack of leg extension, and instability landing (Lu, 2022). This indicates that athletes' physical fitness is crucial to the performance of jumping difficulty movements (Yang, 2015). Figure 1.2 reports the physical fitness survey of Wushu routine athletes in Hebei Province in 2023 (Zhang & Lu, 2023). The basic physical fitness test is scored out of 100 points, with 60 points considered a passing grade and 80 points deemed excellent. A test conducted by researchers in 2023 on 26 Wushu routine athletes from the Hebei Wushu Centre revealed that 7 athletes failed, accounting for 26.92%. The remaining athletes scored at the passing threshold of 60 points, with none achieving the excellent standard of 80 points. The continuous elevation of jumping difficulty in Wushu routine competition rules has been identified as a critical factor affecting athletes' Wushu routine competition results (Huang, 2022). Standard Wushu training methods can no longer meet the higher requirements of new regulations in this new era (Huang, 2022).

The various abilities in Wushu routines, such as jumping, running, kicking, and striking, require excellent physical fitness. Although Wushu routines demand high technical proficiency, the development of skills and physical fitness is complementary; skill training aids in improving physical fitness, and enhanced physical fitness, in turn, ensures the standardisation and accuracy of movements (Zhang & Lu, 2023). The challenging movements in Wushu routines involve multiple joints, upper and lower limbs and core muscle groups (Gao, 2022). Additionally, there needed to be a better match between Wushu routine athletes' upper and lower body strength (Zhang & Lu, 2023). A lack of physical training in athletes will result in a decline in their sense of rhythm, speed, and coordination (Zhang & Lu, 2023). Many Wushu coaches lack expertise in physical training, and the training methods used in Wushu routines continue to have numerous issues (Gao, 2022). Standard Wushu routine physical fitness training often relies on single-resistance weight exercises, emphasising the size of resistance, the number of repetitions, and sets (Su, 2015). However, relying solely on standard training methods with single-joint, single-dimensional, and fixed motion paths to enhance an athlete's local muscle strength is insufficient (Su, 2015). Such a singular standard training model tends to fragment the kinetic chain during training, diminishing the athlete's performance (Fernandez-Fernandez et al., 2016; Fernandez-Fernandez et al., 2020). Furthermore, this standard approach can lead to muscle memory formation, reducing muscle flexibility (Gao, 2022).

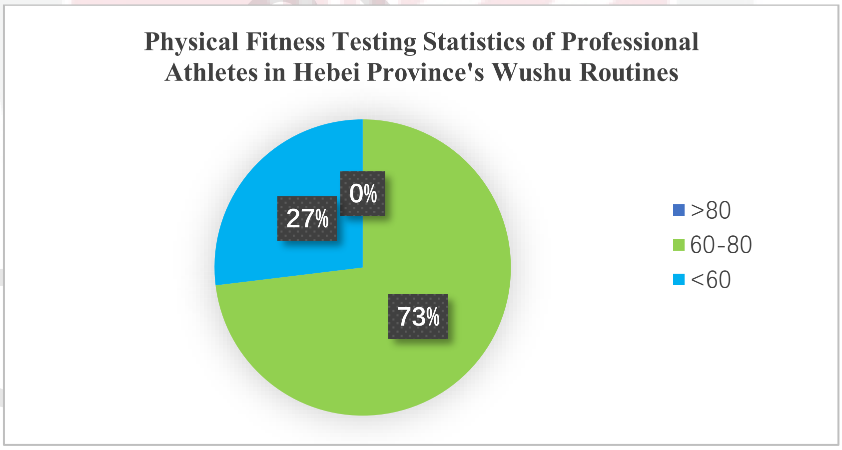

Figure 1.2 : A Survey on Physical Fitness among Wushu Routine Athletes in Hebei Province in 2023

Therefore, during physical fitness training, it is necessary to diversify training methods, using comprehensive training to stimulate various parts of an athlete's body, effectively combining physical fitness training with Wushu technical training and enhancing the scientific basis of athlete training (Gao, 2022). Additionally, Wushu routines are a unique sport that emphasises aesthetics and performance. Like high-difficulty sports such as dance and gymnastics, Wushu demands high-quality athletic performance, making skill training essential (Watson et al., 2017). Research has shown athletes' sports-related injuries are relatively high after standard physical fitness training (Gao, 2022). The severity and frequency of sports-related injuries in Wushu athletes during competitions positively correlate with standard physical fitness training duration (Jia & Zhang, 2022). As the level of competition increases, the frequency and severity of sports injuries also rise (Jia & Zhang, 2022). The primary cause of sports injuries is that standard training methods neglect the means and loads to meet the training goals of different stages of athletes and overlook injury prevention and post-training recovery (Lu, 2022). Therefore, examining training methods for Wushu routine jumping techniques is necessary and complements existing theories (Wei, 2015). To address these challenges, training interventions must focus on enhancing physical fitness components that directly impact jumping difficulty movements: strength, power, speed, endurance, and flexibility. While conventional Wushu training includes resistance exercises, endurance drills, and skill-based techniques, it often lacks progressive overload, variability, and sport-specific neuromuscular adaptations necessary for optimizing athletic performance (Gao, 2022).

At the current stage, it is crucial to develop athletes' physical fitness comprehensively, employ effective training methods, and enhance the performance of wushu routine athletes during the peak competitive stage (Chai & Xiao, 2023). HIFT emerges as an up-and-coming training method (Feito et al., 2018). HIFT integrates various training methods, including muscle strengthening exercises, comprehensive upper and lower limb movements, and core stability training (Heinrich et al., 2012; Kliszczewicz, McKenzie, & Nickerson, 2019). HIFT aims to create a huge metabolic demand through fast, repetitive training with limited or no rest. Due to its short duration and effectiveness, it has recently been popular (Butcher et al., 2015; Claudino et al., 2018; Smith et al., 2013). HIFT emphasises functional multi-joint movements involving multiple muscle groups, joints, planes, and dimensions (Feito et al., 2019). According to Glassman (2010), HIFT can raise testosterone, insulin, and growth hormone levels and increase athletic results.

HIFT effectively enhances cardiovascular endurance, muscle strength, power, agility, balance, and coordination while improving sports-specific skills and preventing injuries (Box et al., 2019; Haddock et al., 2016). HIFT can adopt different training modes according to various sports (such as rowing, cycling, skiing, rock climbing, swimming, and wrestling), training time and load (Falk Neto & Kennedy, 2019).

Why Choose HIFT Over Other High-intensity Training Methods? HIFT was selected as the intervention method for this study because it integrates the characteristics of high-intensity interval training (HIIT) and functional training (FT), offering broader adaptability and specificity for athletic performance. Compared to other high-intensity training methods (e.g., HIIT, resistance training, and speed-agility training), HIFT presents the following advantages:

(1) **Multidimensional Training**: HIFT incorporates multi-joint, multi-directional functional movements, whereas HIIT primarily focuses on short-duration, high-intensity sprints aimed at cardiovascular endurance, with limited emphasis on strength and power development (Feito et al., 2018).

(2) **Sport-Specific Adaptation**: HIFT employs a comprehensive training

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approach that integrates strength, speed, endurance, and agility exercises, whereas traditional resistance training (e.g., weight training) primarily targets muscle hypertrophy and strength rather than holistic athletic performance (Heinrich et al., 2014).

(3) **Movement Pattern Compatibility**: Wushu involves complex jumping, rotational, and explosive movements. HIFT, by incorporating power training, functional load training, and high-intensity circuit training, aligns more closely with the movement demands of Wushu athletes (Glassman, 2010).

Previous research has shown that HIFT is widely adopted across various sports, such as taekwondo (Mischenko et al., 2021), sambo (Kudryavtsev et al., 2023), judo (Osipov et al., 2019), soccer (Hilaiel & Alsulan, 2021), wrestling (Turker & Yuksel, 2020), boxing (Chaabene et al., 2015; Galimova et al., 2018), gymnastics (Zhu, 2023), and volleyball (Bozdogan, 2021). Several studies have affirmed the positive impact of HIFT on athletes' physical fitness (Ambrozy et al., 2022; Avetisyan, Chatinyan, Streetman, & Heinrich, 2022; Mischenko et al., 2021; Osipov et al., 2022; Yuksel, Gündüz, & Kayhan, 2019; Zhu, 2023). Some studies have reported the positive effects of HIFT on athletes' technical performance (Ambrozy et al., 2022; Galimova et al., 2018; Kudryavtsev et al., 2023; Mischenko et al., 2021; Osipov et al., 2017; Osipov et al., 2019; Zhu, 2023). Numerous studies have reported the positive effects of functional training on the physical fitness of Wushu athletes (Cai, 2020; Song, 2015; Sun, 2021; You, 2020; Zhang, 2021; Zhou, 2018), with several studies documenting the positive effects of functional training on athletes' technical performance (Chen, 2020; Fan, 2020; Song, 2015; Sun, 2020). Nevertheless, these studies have predominantly focused on low- and moderate-intensity functional training, and no research has explored the impact of HIFT on Wushu athletes.

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However, most current HIFT studies primarily focus on measuring anthropometric (e.g., height, weight) and physiological parameters (e.g., strength, endurance, speed, agility) (Koopmann et al., 2020). No article applies high-intensity functional training to Wushu sports. Meanwhile, no studies simultaneously examined the five physical fitness components related to wushu routines (strength, power, speed, endurance, flexibility) and jumping difficulty movements. Research on high-intensity functional training for Wushu routines still needs to be explored. In this context, a training strategy that enhances movement strength, speed, stability, and endurance and reduces sports-related injuries is paramount in raising the competitive level of Wushu routine athletes. This study aims to bridge this gap by assessing the impact of high-intensity functional training on physical fitness and jumping difficulty movements of Wushu routine athletes.

While prior research indicates the efficacy of HIFT can improve physical fitness and skill ability in various sports, its benefits for Wushu routine players are limited and need to be investigated further. As a result, this study investigates the advantages of introducing HIFT into Wushu regular training, offering significant information for coaches and players in optimising training programs. This study aims to examine the effects of HIFT on Wushu athletes' physical fitness and jumping difficulty movements. The results of this research are expected to provide valuable insights into developing HIFT training programs for Wushu athletes, ultimately improving their physical fitness and performance in jumping difficulty movements.

1.3 Objectives

The research objectives of this study are divided into general and specific objectives.

1.3.1 General Objective

This study examines the effect of 12 weeks of HIFT on physical fitness and jumping difficulty movements among college male Wushu routine athletes in China, Additionally, the study analysed covariates to assess their potential contributions to the training outcomes, providing a comprehensive evaluation of the intervention program's effectiveness.

1.3.2 Specific Objective

To examine the effect of HIFT across the baseline, post-test 1, and post-test 2 on physical fitness, such as strength, power, endurance, speed, and flexibility among college Wushu routine athletes in China.

To examine the effect of HIFT across the baseline, post-test 1, and post-test 2 on jumping difficulty movements, such as Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault among college Wushu routine athletes in China.

1.4 Hypotheses of the Study

The research hypotheses of this study are divided into general and special hypotheses.

1.4.1 General Hypothesis

There is no significant difference in the effects of 12 weeks of HIFT on physical fitness and jumping difficulty movements of Chinese college male Wushu routine athletes. In addition, covariates did not contribute to the HIFT training results.

1.4.2 Specific Hypothesis

Based on objectives related to physical fitness, including strength, power, endurance, speed, and flexibility. Five specific hypotheses were developed.

H01.1: There was no significant difference in muscle strength between the control and experimental groups among Chinese college male Wushu routine athletes at baseline, post-test 1, and post-test 2.

H01.2: There was no significant difference in power between the control and experimental groups among Chinese college male Wushu routine athletes at baseline, post-test 1, and post-test 2.

H01.3: There was no significant difference in endurance between the control and experimental groups among Chinese college male Wushu routine athletes at baseline, post-test 1, and post-test 2.

H01.4: There was no significant difference in speed between the control and experimental groups among Chinese college male Wushu routine athletes at baseline, post-test 1, and post-test 2.

H01.5: There was no significant difference in flexibility between the control and experimental groups among Chinese college male Wushu routine athletes at baseline, post-test 1, and post-test 2.

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Based on the second objective related to Wushu jumping difficulty movements, including Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault. Four specific hypotheses were developed.

H02.1: There was no significant difference in Flying Kick between the control and experimental groups among Chinese college male Wushu routine athletes at baseline, post-test 1, and post-test 2.

H02.2: There was no significant difference in Whirlwind Kick between the control and experimental groups among Chinese college male Wushu routine athletes at baseline, post-test 1, and post-test 2.

H02.3: There was no significant difference in Outward Leg Swing in Flight between the control and experimental groups among Chinese college male Wushu routine athletes at baseline, post-test 1, and post-test 2.

H02.4: There was no significant difference in Side Somersault between the control and experimental groups among Chinese college male Wushu routine athletes at baseline, post-test 1, and post-test 2.

1.5 Significance of the Study

The research significance of this study is divided into theoretical and practical importance.

1.5.1 Theoretical Significance

This research pioneer applies the Training Load Model (Impellizzeri et al., 2019) and the HIFT Training Theory (Feito et al., 2018) to the specific domain of Wushu. This sport demands a unique combination of physical fitness and jumping difficulty movements. Bridging these two theoretical frameworks opens new avenues for understanding how these athletes' physical performance can be optimised through

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structured training. Despite the widespread use of these theories in various sports and exercise contexts, more research has yet to be conducted on the impact of HIFT on physical fitness and jumping difficulty movements of Wushu routine athletes. The specific interplay between HIFT, physical fitness, and jumping difficulty movements in Wushu athletes remains a relatively uncharted territory. This experiment study seeks to address this knowledge gap by investigating the intricacies of these interactions. Through 12 weeks of HIFT experiments, it is easy to see how HIFT, guided by the Impellizzeri framework, affects the performance of Wushu athletes. This synergistic effect may reveal the complex relationship between training objectives, internal and external training loads, and outcomes. The results of this study can provide valuable insights for Wushu athletes to develop tailored training protocols to improve their physical fitness and jumping difficulty movements, thereby gaining a competitive advantage in this sport.

1.5.2 Practical Significance

This study designed a 12-week high-intensity functional training plan for Wushu routine athletes' physical fitness and jumping difficulty movements based on integrating internal and external training loads and HIFT Training Theory. This study's HIFT training adaptation stage is 1- 4 weeks; the improvement stage is 5-8 weeks; and the consolidation stage is 9–12 weeks. Although multiple studies have shown that HIFT positively impacts athletes' physical fitness and skill performance, more scientific research is needed to determine the potential advantages of HIFT for Wushu athletes' physical fitness and jumping difficulty movements. Therefore, this study examines whether HIFT training positively impacts Wushu routine athletes' physical fitness and jumping difficulty movements. If the intervention experiment produces

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positive results, it can help practitioners optimise their training plans and meet the unique needs of Wushu routines. In addition, coaches and sports researchers may utilise this knowledge to better control athletes' training loads, allowing Wushu athletes to perform better in Wushu jumping difficulty movements training. The insights obtained from this study can be applied to a broader range of sports and physical education disciplines, contributing to the continuous development of knowledge systems in sports science and HIFT.

1.6 Limitation of the Study

The first limitation of this study pertains to participants' dietary habits. Various types of food have different impacts on physical fitness and training effectiveness. It is challenging to ensure that all participants consume the same food quality during the experiment, which may increase the variability of the experimental results. In addition, participants may consume some snacks or drinks, which can affect the calculation of total calories. In practical operation, it is difficult to carry out strict dietary interventions. To minimise the impact, the university provides centralised catering and accommodation facilities for all participants. The university offers a standard diet package of two meat and two vegetables to facilitate dietary control for participants. Researchers will record the diet of participants throughout the experiment. Moreover, training instructors advised participants to maintain their dietary habits during the experiment, and participants agreed not to alter their nutritional routines, as evidenced by their signed informed consent forms. (For detailed information, please refer to Appendix D)

The second limitation of the study pertains to participants' exercise habits. Outside of the athlete training intervention, there might be additional fitness exercises in which participants habitually engage, potentially impacting the effectiveness of the 12-week HIFT intervention. To minimise the impact, all participants in this study need to follow the researchers' arrangements and not engage in additional exercise activities during the 12 weeks of the HIFT training intervention. Participants agree to sign an informed consent form. In addition, the researchers also discussed with the coach, who would remind participants to adhere strictly to the experimental intervention plan every week.

The third limitation concerns the participants' motivation to participate actively in the experiment. High-level motivation can encourage participants to focus more on training and invest more effort, thereby improving training effectiveness and the reliability of experimental results. Throughout the experiment, the coach conveyed the training objectives and expectations to participants, enabling them to understand the importance and potential benefits of HIFT training. Meanwhile, the coach emphasised that the evaluation results of participants will affect their final exam scores. In addition, the coach also conveyed to the participants that excellent performance in experimental training will enhance their prospects of achieving exceptional results in Wushu routine competitions. This external motivation strategy aims to enhance participants' self-efficacy, and internal motivation during the intervention was effective.

1.7 Delimitation of the Study

The scope of this study has been defined in the following aspects.

(1) The participants in this study are 18-22-year-old college male Wushu routine athletes who are college students majoring in physical education

and have at least three years of professional training experience in Wushu routines before being admitted to the college. Completing jumping movements in Wushu routines requires a solid foundation, so the selected athlete must be able to complete the basic jumping movements in Wushu routines.

(2) Based on a review of relevant literature, this study's intervention design is a high-intensity functional training intervention plan developed for 12 weeks, three times a week, for 60 minutes each, targeting Wushu routine athletes' physical fitness and jumping difficulty movements (Ambroży et al., 2022; Chen, 2020). According to Competition Regulations for Wushu Routine Events at the 14th China sports meeting, this study focuses on the strength, power, speed, endurance, and flexibility of physical fitness variables, and the Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault of jumping difficulty movements.

1.8 Definition of the Study

This study defines critical terms from two aspects: conceptual definition and operational definition.

1.8.1 High-Intensity Functional Training

Conceptual Definition: HIFT is a functional fitness method with relatively high training intensity (Feito et al., 2018), which integrates multiple training methods such as muscle strengthening training, upper and lower limb comprehensive exercise, and core stability training. Its goal is to optimise athletes' exercise efficiency relatively quickly (Heinrich et al., 2012; Kliszczewicz et al., 2019). HIFT replicates real-life exercise needs by combining high-intensity functional movements (Buckley et al., 2015). By integrating cardiovascular, neuromotor, and muscle function through aerobic and anaerobic exercise strategies, HIFT can trigger more muscle recruitment

(Heinrich et al., 2021; Wilke & Mohr, 2020). HIFT can stimulate neuroendocrine responses, increase testosterone, insulin, and growth hormone, and improve exercise performance (Glassman, 2010).

Operational Definition: The researchers used Greg Glassman's (2010) "CrossFit training guide" to develop a high-intensity functional training program based on Wushu routine features. This study's high-intensity functional training program involves multiple training methods, aiming to stimulate various physical qualities, including strength, power, endurance, speed, and flexibility, through high-intensity exercise relatively quickly. HIFT training through diversified training modes to avoid training singularity and ensure maximum training effectiveness. For example, combining strength and aerobic training can improve physical fitness. The training intensity of HIFT is usually between 70%-90% to ensure efficient stimulation. The training interval is relatively short, usually 10-30 seconds, to maintain a high heart rate and metabolic state.

1.8.2 Physical Fitness

Conceptual Definition: Physical fitness refers to the ability of the body to function effectively (Avetisyan et al., 2022). These abilities consist of at least five health-related and six skill-related physical qualities, each improving life quality (da Silva et al., 2022). Physical fitness is associated with a person's capacity to work efficiently, enjoy leisure time, stay well, fight low-motivation diseases or disorders, and respond to crises. Although the development of physical fitness results from multiple factors, without regular sports activities, the best physical fitness is impossible (Roy et al., 2010). Various components of bodily function are independent but also interrelated.

Any sport requires sufficient health-related, skill-related, and metabolic components (Roy et al., 2010).

Operational Definition: According to the competition regulations of the 14th National Games of China, Wushu athletes must undergo physical fitness tests, including strength, power, speed, endurance, and flexibility. The physical fitness tested in this study also includes strength, power, speed, endurance, and flexibility. More specifically, the push-ups involved in this study were used to test muscle strength; the standing long jump was to test power; the jumping rope was used to test endurance; the sprint 30 m was used for testing speed and sit-and-reach for testing flexibility.

1.8.3 Jumping Difficulty Movements

Conceptual Definition: Wushu routines emphasise the standardisation of action quality, the competitiveness of action difficulty, and the appreciation of action performance. Jumping difficulty movements are an essential component of Wushu routine competitions, and a complete series of Wushu routine jumps requires athletes to maintain a strong braking force and perfect spatial orientation abilities (Cheng et al., 2012). According to the "*Rules and Judgement Law of Wushu Routine Competition*" (2012), approved by the Chinese Wushu Association, Wushu routine athletes must include at least one jumping difficulty movement during the drill process. The basic jumping difficulty movements in Wushu routines include the Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault. Each jumping difficulty movement consists of four steps: running up, taking off, air spin, and landing. Jumping and turning movements are further divided into 180 °, 360 °, 540 °, and 720 ° based on the degree of rotation.

Operational Definition: The Wushu routines involved in this study are the jumping difficulty movements stipulated by the rules of competitive Wushu routines, mainly including Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault. The quality of movements, such as run-up, take-off, air spin, and landing stability, influences the performance of soaring movements in Wushu routines. This jumping difficulty movement performance largely depends on the human body's physical fitness and technical level.

1.8.4 Wushu Routine Athletes

Conceptual Definition: Wushu routine athletes refer to those who are registered with the Chinese Wushu Sports Management Centre and specialise in practising the Wushu routine and performing themselves in Wushu competitions (Zheng, 2011). Wushu routine athletes aim to create excellent athletic performance and win competitions (Gao, 2022). Wushu routine athletes are divided into competitive and traditional Wushu routine athletes based on their sports events (Qi, 2010). The technical level of Wushu routine athletes includes six levels: international Wushu athletes (international level athletes), Wuying Wushu athletes (national level athletes), first-level samurai (level 1 athletes), second-level samurai (level 2 athletes), third-level samurai (level 3 athletes), and samurai (young athletes) (Qi, 2010). The development of excellent Wushu routine athletes can be divided into four stages: the foundational training stage, the specialised improvement stage, the peak competitive stage, and the competitive maintenance stage (Gao, 2022). Wushu routine athletes in the peak competitive stage are generally between 18 and 23 years old.

Operational Definition: Completing jumping-difficult movements in Wushu requires practitioners to have a high level of basic Wushu skills, and there is a high risk of sports injury during the practice process. Practitioners must possess good Wushu specialised physical fitness. Therefore, Wushu students from the sports college are the best choice for this study, as college athletes gradually mature in body shape and have indicators close to those of adults. They also possess particular Wushu routine technology and theoretical knowledge (Gao, 2022). In addition, sports universities have more professional coaches and training facilities, which are crucial for athletes to improve their sports skills and are also a source of talent for major national sports competitions and professional sports teams. The enrolment standard of the sports college is that students must obtain a national level 2 or higher Wushu athlete certificate. The Wushu routine athletes in this study are competitive Wushu routine athletes from the Hebei Institute of Physical Education class, aged 18-22 years. Before being admitted to college, they had at least three years of Wushu practice experience. All Wushu routine athletes participating in the study have a technical level of national second-level samurai (Level 2 athletes) or above.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will review the main literature related to this study and then discuss the theoretical framework applied in this study (2.2) Chinese Wushu; (2.3) Chinese Wushu routine; (2.4) The current situation of Chinese Wushu routine athletes; (2.5) High-intensity functional training; (2.6) The impact of high-intensity functional training on athletes' physical fitness and sport-specific performance; (2.7) The effect of functional training on the jumping skills of Wushu routine athletes; (2.8) Theoretical framework; And (2.9) conceptual framework.

2.2 Chinese Wushu

Wushu, as an integral part of traditional Chinese culture, boasts a rich history and profound cultural heritage. Modern Wushu has gradually evolved into competitive Wushu, with its core objectives centred on achieving technical performances that are "higher, more difficult, aesthetically pleasing, and innovative." However, in recent years, the development of Wushu has faced significant challenges due to relatively standard training methods and a lack of awareness regarding athlete protection. This is particularly evident in the insufficient innovation of high-difficulty jumping techniques (Yang & Guo, 2016). Against this backdrop, HIFT Training, a method integrating multi-joint movements, strength, endurance, and flexibility development, has emerged as a promising approach to addressing the limitations of traditional Wushu training.

2.3 Chinese Wushu Routine

The competitive Wushu routine is a competitive sports event that inherits traditional Wushu, is influenced by Western sports, conducts exercises and evaluations under unified standards, has specific quantitative scales, is limited by rules, has certain practical goals, and has specific forms of expression (Li, 2022). In the early days of founding the People's Republic of China, Wushu was designated an official competition (Sun et al., 2020). The National Sports Commission proposed the development direction of Wushu techniques with high difficulty, high quality, and beautiful image (Li, 2022). Since then, the development concept of "high, difficult, and beautiful" has become the goal of athletes in various teams (Yang & Guo, 2016).

In the 1990s, it was clarified that routine techniques should reflect the technical development direction of "high, difficult, new, and beautiful" competitive Wushu routines while maintaining the essential characteristics of Wushu (Gao, 2022). At present, competitive Wushu routines are modern competitive sports events mainly based on actions with offensive and defensive meanings, arranged according to contradictory laws such as offensive and defensive advance and retreat, slow movement and stillness, rigidity, softness, and virtuality (Li, 2022). The main feature is competitive competition, and the main goal is to create excellent sports results and win the competition (Gao, 2022). Traditional Wushu training programs primarily consist of fundamental skill training, repetitive practice of routine movements, as well as strength and endurance exercises (Lu, 2021). These programs typically emphasize low to moderate intensity and are guided by specific movement standards and routine requirements. While standard training methods focus on the continuity, coordination, and refinement of techniques, they lack the integration of high-intensity functional

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training (Gao, 2022). Although effective in honing technical precision, this approach may be limited in its ability to comprehensively enhance athletes' physical fitness, such as power, endurance, and flexibility. This limitation becomes particularly evident when addressing the demands of modern competition, which increasingly emphasise high-difficulty jumping techniques.

2.4 The Current Situation of Chinese Wushu Routine Athletes

Participants in Wushu routine competitions must register with the Wushu Sports Management Centre of the General Administration of Sport of China (Li, 2022). Wushu routine athletes are divided into competitive and traditional Wushu routine athletes based on their sports events (Qi, 2010). The technical level of Wushu routine athletes includes six levels: international Wushu athletes (international level athletes), Wuying Wushu athletes (national level athletes), first-level samurai (level 1 athletes), second-level samurai (level 2 athletes), third-level samurai (level 3 athletes), and samurai (young athletes) (Gao, 2022) .

To achieve good results, Wushu routine athletes prioritise the training of jumping difficulty movements (Yu, 2017). The jumping difficulty movements in Wushu routines are the main elements that highlight the competitiveness and artistry of competitive Wushu (Yang & Guo, 2016). With the development of competitive Wushu, jumping difficulty techniques have become the dominant factor affecting the final score of the competition (Qi, 2010). The completion of jumping difficulty movements plays a decisive role in the performance of the competition. Jumping difficulty movements include Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault (Gao, 2022). However, after the 2008 Beijing Olympics, the

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development of competitive Wushu fell into a bottleneck, mainly due to the lack of new development in jumping difficulty movements and outdated training methods for Wushu routine athletes (Yang & Guo, 2016).

Due to a lack of scientific training and self-protection awareness, athletes can easily suffer injuries (Deng, 2019). A study has investigated the current development status of competitive Wushu in Hunan Province and found that in recent years, the proportion of athletes suffering from sports injuries in competitive Wushu training has been increasing, and athletes participating in competitive competitions have experienced certain sports injuries (Deng, 2019).

Moreover, coaches' training methods are relatively traditional, and most coaches are unfamiliar with specialised scientific training models (Wei, 2015). To strengthen the difficulty of jumping movements, coaches adhere to the "continuous practice" training method, which increases the probability of athletes suffering from sports injuries (Deng, 2019). Those with severe sports injuries even withdraw from competitive Wushu (Deng, 2019) .

2.5 High-Intensity Functional Training

High-intensity functional training is a new training method CrossFit promotes (Feito et al., 2018). It is loved by athletes worldwide (Haddock et al., 2016; Poston et al., 2016). Feito et al. (2018) conducted a theoretical study on HIFT and explored its significance in improving physical fitness. HIFT is defined as a kind of functional fitness method with relatively high training intensity in different training programs, which emphasises multi-joint, functional, high explosive strength and lasting whole-

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body exercises, such as strength exercise combined with aerobic exercise and self-weight exercise (Feito et al., 2018; Feito et al., 2019). HIFT requires many different types and lengths of training, which are occasionally completed without interruption. HIFT combines rapid repetition of multi-joint movements with minimal rest time, creating significant metabolic demands and recruiting more muscles. This demand promotes enhancing muscle strength, hypertrophy, and adaptation to aerobic endurance. Kliszczewicz (2019) and Heinrich (2012) share the same view. They both believe that HIFT integrates multiple training methods such as muscle strengthening, upper and lower limb comprehensive sports and core stability training. Its unique training methods can be applied to sports such as weightlifting and aerobics in the Olympic Games. The fundamental purpose is to enhance the efficiency of athletes in completing actions in a relatively short time (Heinrich et al., 2012; Kliszczewicz et al., 2019). At present, the Workout of the Day (WOD) exercise, "Fran" exercise and "Cindy" exercise are popular methods of combining HIFT abroad (Brisebois et al., 2018; Feito et al., 2018).

Functional training mixed with multidimensional integrated sports chains systems like nerves, muscles, and bones promotes particular sports talents (Long & Li, 2013; Wang, 2017). Carnes and Mahoney studied a group of leisure runners by combining HIFT with interval training and other training modes and found that HIFT is the most time-saving training strategy (Carnes & Mahoney, 2019). The applicability of HIFT goes beyond traditional fitness programs. It can be customised according to specific sports, individual physical conditions, training time and load requirements. Previous studies have shown that HIFT positively impacts the physical performance of different populations, including obese individuals (Brandt et al., 2023), older adults (Rivas-

Campo et al., 2022), healthy young females (Bahremand et al., 2023), adolescents (Eather et al., 2016), wrestlers (Türker & Yüksel, 2020), Taekwondo athletes (Mischenko et al., 2021), gymnasts (Zhu, 2023), and recreational runners (Carnes & Mahoney, 2019).

To comprehensively evaluate the effects of training interventions on athletes' physical fitness and sport-specific performance, it is essential to compare the standard training methodology typically used by Wushu athletes with the experimental HIFT Training. Table 2.1 summarises the differences based on form, benefits, limitations, and advantages.

Dimension	HIFT Training	Standard Training
Form	• Integrates multi-joint, high-intensity, and functional movements. • Combines cardiovascular, strength, and power exercises into a single session (e.g., squats, burpees, plyometrics). • Structured as circuit-based workouts with minimal rest.	• Focuses on repetitive low-to-moderate-intensity movements. • Emphasises mastering technical movements and Wushu routines (e.g., strikes, kicks, and stances). • Includes isolated strength training, endurance runs, and flexibility exercises.
Benefits	• Enhances physical fitness components (strength, power, endurance, speed, and flexibility) in a time-efficient manner. • Supports athletes in meeting the demands of modern Wushu competitions requiring high-intensity and explosive movements.	• Effective for refining technical skills and developing movement consistency. • Provides a solid foundation for beginners to improve balance and coordination.
Limitations	• Requires proper supervision to prevent overtraining and injury risk due to high intensity. • Demands a higher level of physical readiness, which may not be suitable for beginners.	• Lacks sufficient intensity to improve power, speed, and endurance effectively for advanced athletes. • Focuses on isolated movements, leading to limited improvements in functional movement patterns.
Advantages	• Increases athletes' ability to perform jumping difficulty movements (e.g., Flying Kick, Whirlwind Kick). • Fosters adaptation to competitive scenarios involving repeated high-intensity efforts.	• Promotes technical precision and mastery of Wushu routines. • Easier to implement due to standardised protocols and minimal equipment requirements.

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2.6 Effect of High-Intensity Functional Training on Physical Fitness and Sport-Specific Performance of Athletes

Athletes' competitive abilities are determined by their physical fitness and sport-specific performance (Franchini et al., 2014). Specialised sports performance refers to an athlete's ability and efficacy in specialised sports operations. Physical fitness is the cornerstone for specialist sports performance, with muscular strength, endurance, and agility all positively influencing athletes' movement speed. Chaabene et al. (2015) identified a link between upper and lower body muscular strength and boxers' ability to throw fast blows. Basketball players require excellent cardiovascular fitness to remain in competition (Hovsepian et al., 2021), and strong quadriceps muscles can improve hiking ability (Bourgois et al., 2017). Hip joint mobility is critical for taekwondo athletes' striking ability.

Furthermore, Pan et al. (2022) found that players' muscle strength, flexibility, power, muscular endurance, and cardiac health all influence single-handed dinghy competition performance. Athletes must develop physical traits including muscle strength, power, and endurance to perform well in tournaments (Fernandez-Fernandez et al., 2016; Podrigalo et al., 2019). The crucial elements of physical fitness studied in a system review are muscle strength, power, endurance, agility, and flexibility. This review summarises the following content: (2.6.1) Effect of HIFT on the muscle strength of athletes; (2.6.2) Effect of HIFT on the power of athletes; (2.6.3) Effect of HIFT on the endurance of athletes; (2.6.4) Effect of HIFT on the agility of athletes; (2.6.5) Effect of HIFT on the flexibility of athletes; (2.6.6) Effect of HIFT on sport-specific performance of athletes; And (2.6.7) some gaps based on the above system review.

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2.6.1 Effect of HIFT on the Muscle Strength of Athletes

Numerous investigations have demonstrated that combining strength and endurance training may generate interference effects, negatively impacting athletes' training outcomes (Coffey & Hawley, 2017; Fyfe et al., 2014; Murach & Bagley, 2016; Wilson et al., 2012; Wong et al., 2010). This interference effect, however, may not be detected when athletes participate in HIFT training (Falk Neto & Kennedy, 2019). A meta-analysis was conducted to investigate the impact of HIFT on upper-body muscle strength (ES=0.414) and lower-body muscle strength (ES=1.051). This systematic review comprised six studies that assessed participants' upper-body muscle strength in taekwondo, wrestling, judoka, and aerobic gymnastics. These results are consistent with those of De Sousa et al. (2016), who examined the impact of HIFT on lower-limb muscular strength among adolescents. According to Barfield et al. (2012), HIFT training improves lower-limb muscular strength more effectively than upper-limb muscular strength.

Unlike earlier publications, Heinrich et al. discovered using 1RM testing that the experimental group improved upper limb muscular strength more significantly following HIFT intervention (Heinrich et al., 2012). Muscle contraction activates the c-Jun N-terminal Kinase (JNK). HIFT training increases JNK activity, which enhances protein synthesis and may boost muscular strength (Ben-Zeev & Okun, 2021). Previous studies have shown that weightlifting in HIFT training regimens may considerably improve individuals' muscular strength (Barfield et al., 2012; de Sousa et al., 2016; Heinrich et al., 2012). Participants regularly encounter muscular failure during the HIFT training, improving muscle strength at varied repetition rates. Yuksel et al. (2019) discovered that an eight-week period of HIFT increased amateur

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wrestlers' push-up scores.

Muscle strength is important in various taekwondo motions, including Flying Kick, Whirlwind Kick, and quick actions (Bridge et al., 2014). Mischenko et al. (2021) observed that following nine months of HIFT intervention, female taekwondo players greatly benefited from modified pull-ups. One study comprised of this assessment contrasted the impact of CrossFit exercise with conventional taekwondo training and discovered that the CrossFit exercise group dramatically improved participants' pull-ups and push-ups. Pull-ups showed no significant change from the control group. However, there were significant statistical differences in push-ups (Ambrozy et al., 2022).

A current investigation discovered that aerobic gymnasts improved their side-throw medicine ball ability after nine weeks of CrossFit training (Zhu, 2023). Osipov et al. (2022) found that an eight-week HIFT course enhanced muscular strength abilities among elite judokas. However, there was no significant statistical difference in lower limb strength between the experimental and control groups in the squat test (Osipov et al., 2022). As a result of our meta-analysis, HIFT appears to be a beneficial strategy for improving players' upper and lower-limb muscular strength ability.

2.6.2 Effect of HIFT on the Power of Athletes

Multiple investigations propose that HIFT may immediately offer increases in strength by boosting muscle potency (de Sousa et al., 2016; Heinrich et al., 2012; Hermassi et al., 2019). According to the meta-analysis, HIFT showed a moderate influence on players' strength ability when in contrast to the control group (ES=0.499). Compared

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to traditional strength exercises, these advances in power assessment have a greater connection with the notion of training specificity. Changing the HIFT training protocol can improve the efficacy of power training for players (Crawford et al., 2018; Kliszczewicz et al., 2018). Power refers to the capacity of the body to create maximum force rapidly following quick muscular contractions, and it increases with the length of force generation (Gerhart, 2013). Based on the force-velocity curve, differing training methodologies within different levels can boost the rate of force growth at each point on the curve, consequently optimising the advantages of power production (Haff & Nimphius, 2012; Suchomel et al., 2017).

Recent meta-analyses additionally discovered that strength training enhances teenage activity levels (Behm et al., 2017). Six studies were included in this systematic review to analyse the effect of HIFT on the strength ability of male Wushu players and female volleyball players, and significant gains were found. This study shows that HIFT can successfully improve players' strength. These results resonate with Adami et al. (2022), who compared the physiological attributes of HIFT, endurance, and power athletes, unveiling the function of HIFT in amplifying male power. Adami et al. (2021) discovered that 20 HIFT athletes performed exceptionally well in power-related elements.. Notably, Caloglu and Yuksel (2020) observed a positive impact on the power indicators of wrestlers after eight weeks of HIFT. Moreover, myriad studies spanning various sports underscore the usefulness of HIFT in augmenting players' power prowess (Avetisyan et al., 2022; Bozdogan, 2021; Mischenko et al., 2021; Türker & Yüksel, 2020; Yuksel et al., 2019). Consequently, our meta-analysis provides substantial support affirming the affirmative influence of HIFT on athletes' power performance.

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2.6.3 Effect of HIFT on the Endurance of Athletes

Endurance is a pivotal element for athletes in maintaining elevated sports performance over a prolonged duration (Senefeld & Joyner, 2020). The meta-analysis underscores that HIFT substantially influence athletes' endurance abilities (ES=0.831). In sports characterised by protracted competitive intervals, endurance unequivocally shapes athletes' outcomes, notably in disciplines such as soccer (Makhlouf et al., 2016), swimming (Perna et al., 2018), cycling (Aagaard et al., 2011), basketball (Hovsepian et al., 2021), boxing (Chaabene et al., 2015), and judo (Franchini et al., 2011). HIFT emerges as a potent alternative to standard endurance exercise methodologies (Adami et al., 2022).

Vigorous training at elevated intensities, encompassing diverse movement patterns, efficaciously fosters musculoskeletal and metabolic adaptations (Heinrich et al., 2014). The human body adapts to high intensity demands by increasing both the size and number of muscle fibres, while simultaneously improving the oxygen delivery capacity of the cardiovascular system. These adaptations elevate athletes' endurance thresholds, enabling prolonged physical exertion (Armstrong & Barker, 2011). Four research in this systematic review investigated the effect of HIFT on Wushu athletes' endurance performance. The beneficial impact is attributed to the improvement of muscular endurance, lactate tolerance, and aerobic performance among athletes who receive HIFT training. Furthermore, the brief yet strong aerobic interval training of HIFT, along with the multidimensional high-intensity repeated training, contributes to enhancing the cardiovascular system's adaptability. This, in turn, facilitates the efficient conveyance of oxygen and nutrients to muscular cells, concurrently retarding lactate buildup and bolstering players' lactate tolerance.

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Previous studies suggested that cardiovascular health, workout economy, and lactate buildup may impact players' ability (Rønnestad & Mujika, 2014). Armstrong and Barker, furthermore, identified a more pronounced cardiorespiratory function in elite young athletes (Armstrong & Barker, 2011). Adami et al. (2022) corroborated that HIFT significantly increased participants' endurance levels. In a cross-sectional evaluation of physiological distinctions between HIFT, endurance, and strength athletes, Green et al. (2023) disclosed comparable endurance abilities between HIFT participants and their endurance-trained counterparts. Conversely, Gavanda et al. (2022) ascertained that, unlike typical strength and endurance training, HIFT successfully improves endurance levels in teenagers. This outcome aligns seamlessly with Bozdoğan (2021)'s investigation, elucidating the beneficial effects of a twelve-week high-intensity exercise program on the cardiovascular fitness in volleyball participants. Ambroży et al. (2022) scrutinised the Cooper test outcomes of 60 male taekwondo players, revealing noteworthy enhancements in the 12-minute continuous sprinting times following the HIFT training.

2.6.4 Effect of HIFT on the Agility of Athletes

Agility, denoting athletes' adeptness at swift reactions within a brief temporal span (Dawes, 2019), emerges as a focal attribute in our meta-analysis, revealing the influence of HIFT on athletes' agility abilities to be of marginal consequence (ES=0.247). HIFT inherently incorporates an array of expeditious and explosive manoeuvres, prominently manifested in exercises like clean and jerk and box jump training (Box et al., 2019). These dynamic actions necessitate the rapid generation of force post-curtailment, augmenting neural prowess for prompt reactions and endowing the body with precision in responding to swiftly evolving environments (Deng et al.,

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2023). Gary Grey's "Chain Reaction Exploratory Theory" intricately intertwines with agility training for athletes (Kearns, 2010).

Agility, commonly exhibited through an athlete's adeptness in managing body posture and effecting swift directional shifts (Liang et al., 2019), is influenced significantly by speed, muscle strength (Nimphius et al., 2010), and balance (Sporis et al., 2010). Proficiency in agility empowers athletes to execute diverse manoeuvres expeditiously during competitions, maintain superior control over their body stance, and seamlessly showcase personal skills, heightening their competitive edge (Delextrat et al., 2015). HIFT accentuates multi-joint and high-intensity actions, positively impacting the human physique's neural-muscular coordination and proprioceptive faculties (Feito et al., 2018). Three studies enfolded within this systematic review scrutinised the agility abilities of volleyball and Wushu players. These results resonate with the outcomes delineated by Carvutto et al. (2021), who observed noteworthy enhancements in players' agility abilities, but without statistical significance, in contrast to the control group.

Moreover, Hovsepian et al. (2021) found considerable gains in agility ability for experimental and control group participants following HIFT training, albeit sans statistically significant disparities between the two cohorts. Ambroży et al. (2022) unearthed that, Taekwondo practitioners improved their shuttle run ability following eight weeks of HIFT, with the study underscoring a noteworthy association between the advancement in shuttle run speed and the specific quality of hip joint rotation speed. Swift movements constitute the bedrock for achieving technical and tactical objectives in combat and defence scenarios (Ouergui et al., 2021).

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2.6.5 Effect of HIFT on the Flexibility of Athletes

Flexibility, denoting the capacity of muscles and joints to extend, is paramount in augmenting the freedom of action and muscular suppleness in individuals (DeBlauw, 2018; Kemmochi et al., 2018). Our meta-analysis unequivocally reveals that HIFT substantially influence on athletes' flexibility abilities (ES=3.167), encapsulating the particular spectrum of muscle activation or muscular aptitude (Kemmochi et al., 2018). With whole multi-joint exercise, muscles, and joints experience adaptation metamorphoses precipitated by extending and contraction, fortifying participants' joint stability and muscular pliancy (Chaabene et al., 2012).

The sit-and-reach test, a staple in assessing flexibility (Kaur et al., 2015), served as a metric in three studies encompassed within this systematic review that delved into the influence of HIFT on the flexibility abilities of aerobic gymnasts and Wushu athletes. These results harmonise with the conclusions drawn by Chizewski et al. (2021), who discerned the efficacy of a seven-week HIFT regimen in enhancing athletes' flexibility. Optimal flexibility accrues benefits in refining muscle efficiency (Zhu, 2023), and incorporating stretching exercises aids in amplifying muscle flexibility, activating the neurological system, and averting sports-related injuries (Liang et al., 2019). Moreover, many studies accentuate the pivotal role of flexibility in shaping athletes' performance (Behm, 2018; Racil et al., 2019). Of significance is the multifaceted repertoire of functional movements within HIFT, prominently featuring clean jerks, squats, and lunges, which emerge as pivotal catalysts in elevating athletes' joint flexibility (Falk Neto & Kennedy, 2019). Cosgrove et al. (2019) performed a noteworthy study demonstrating that, following six months of HIFT, all adults had greater flexibility. Similarly, Zagdsuren et al. (2015) discovered that following a ten-

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week HIFT routine, all male and female flexibility improved considerably.

2.6.6 Effect of HIFT on Sport-Specific Performance of Athletes

The sport-specific performance incorporates athletes' mastery and efficacy in certain athletic procedures, serving as the basis for generating extraordinary competitive outcomes (Serafini et al., 2018). Our meta-analysis reveals that HIFT has a substantial influence on athletes' sport-specific ability (ES=3.351). Athletes may capitalise on their technical brilliance and make wise selections when proficient in sport-specific skills and strategy application. For instance, rapid offensive ability enables athletes to exploit openings while competitors' defences continue to be constructed (Fellingham et al., 2013). Athletes with solid attacking abilities can conduct stronger offensive activities, putting pressure on opponents (Campos et al., 2012). This systematic review comprises seven studies that examine the impact of HIFT on athletes' skill levels. According to De Sousa et al. (2016)'s findings, HIFT dramatically enhanced male vertical jump ability in males. According to Hermassi et al. (2019), HIFT regimens successfully improved the vertical jump ability of elite handball practitioners.

Additionally, Hilaiel and Alsulan (2021) discovered that HIFT procedures increased the shooting precision among five-a-side football participants. Prior studies have demonstrated that HIFT enhances athletes' quickness and precision in assaults (Sprey et al., 2016). Athletes must cultivate full physical fitness to wield tactics with delicacy and increase their competitive prowess (Lee et al., 2015; Santana & Fukuda, 2011). Mischenko et al. (2021) observed that following nine months of training HIFT, young female World Taekwondo Federation (WTF) taekwondo competitors saw a considerable increase in attack speed and battle endurance. Özgür et al. (2022)

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reported that HIFT training significantly increased vertical jump ability in taekwondo competitors. Galimova et al. (2018) asserted that a twelve-week HIFT training dramatically increased the striking ability of college boxers. Furthermore, Pawlak et al. (2015) discovered that 12 weeks HIFT training improved firefighters' ability in simulated firefighting activities.

2.6.7 Conclusion of the Effect of HIFT among Athletes Based on System Review and Meta-Analysis

To better understand the influence of HIFT training on athletes, the author of this study wrote effects of HIFT on physical fitness and sport-specific performance among the athletes: A systematic review with meta-analysis. This systematic review with meta-analysis has been published in "Plos one" journal (Wang et al., 2023). An in-depth search was performed on PubMed, Scopus, Web of Science, EBSCOhost, and Cochrane Library to select relevant literature. Detailed information on PRISMA and publications can be found in the appendix. At the same time, this review also shows some gaps related to this study: (1) intervention gap, (2) population gap, and (3) outcome gap.

(1) Intervention Gap

This systematic review includes 13 publications, focusing on HIFT in various sports such as gymnastics (Zhu, 2023), volleyball (Bozdogan, 2021), taekwondo (Mischenko et al., 2021), sambo (Kudryavtsev et al., 2023), boxing (Galimova et al., 2018), judo (Avetisyan et al., 2022; Osipov et al., 2022; Osipov et al., 2019), kickboxing (Ambrozy et al., 2022), Wushu (Osipov et al., 2017), and wrestling (Türker & Yüksel, 2020; Caloglu & Yuksel, 2020; Yuksel et al., 2019). However, an intervention gap was found

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- none of the studies focused on HIFT in Wushu routines. Due to limited research, many sports have already benefited from HIFT training, but Wushu has not. In addition, no article had an intervention frequency and length of three times a week for 12 weeks.

(2) Population Gap

In this systematic literature review, there are one article about aerobic gymnasts, one article on volleyball players, one article on Sambo athletes, one article on boxing athletes, one article on comprehensive Wushu athletes, two articles on taekwondo athletes, three articles on judo athletes, and three articles on wrestling athletes. Among them, greater study on the influence of HIFT on Wushu athletes is required. Previous studies have shown that HIFT can help improve physical fitness and sports-specific skills in other sports, but it has not been studied in Wushu yet, especially in Wushu routines.

(3) Outcome Gap

In this systematic review, six studies examined the influence of HIFT on athlete muscle strength performance, seven studies focused on power performance, four studies focused on endurance performance, three studies focused on agility performance, three studies focused on flexibility performance, and seven studies focused on sports specific performance. However, research focusing on speed performance is limited. There needs to be a comprehensive study on the six components of athletes' physical abilities (strength, power, speed, endurance, and flexibility). According to the review results on sports performance, most studies have focused on attack speed and race performance, with only one study related to athletes'

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jumping difficulty movements. Therefore, it is necessary to study the influence of HIFT on Wushu athletes' physical fitness and jumping difficulty movements.

2.7 Effect of Functional Training on Jumping Performance in Wushu Routine Athletes

A previous systematic review has examined the influence of functional training on athletes' physical fitness (Xiao et al., 2021). However, it should be noted that the database search for that systematic review did not include the CNKI database, and the included literature did not specifically address the Wushu athletes. Consequently, the researchers of this study performed a systematic review to explore the effect of functional training on the jumping performance of Wushu athletes. This systematic review titled "Effects of Functional Training on Jumping Performance of Wushu Athletes" was published in "Heliyon" Journal (Wang et al., 2024). This literature search utilised global databases, including EBSCOhost, Scopus, PubMed, Web of Science, CNKI, and Google Scholar. After screening, 16 articles fulfilled the inclusion criteria. The appendix contains PRISMA diagrams and complete information for these publications. This evaluation reveals a research gap in the influence of functional training on jumping performance.

2.7.1 Effect of Functional Training on Jumping Performance of Wushu Routine Athletes

Jumping is a fundamental athletic talent required of athletes (Bosco & Komi, 1979). Two investigations have highlighted the favourable influence of functional training interventions on the complexities of high-difficulty leaps in Wushu (Song, 2015; Sun, 2020). The cohesiveness capacity in completing high-difficulty leaps improved significantly after a 12-week functional training routine, while noticeable gender-

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specific effects emerged in the female athlete group. There was no statistically significant difference in performance between female individuals in the Functional Training (FT) group and their counterparts in the control group, especially in the standing long jump (Song, 2015). Another investigation discovered that following the functional training intervention, both the experimental and control groups improved their vertical jump performance, with the experimental group showing a considerably greater improvement. During the peak times of aerial manoeuvres, the mean score for athletes in the FT group increased by 1.67, representing a 33.4% increase.

Similarly, the average result for complicated rotational motions improved by 0.78, representing a 15.8% rise. Furthermore, the mean score for lateral Somersault increased by 3.58, representing a stunning 71.6% increase (Sun, 2020). As a result, in contrast to the control group, the experimental cohort that received functional training showed a more substantial performance improvement.

Separate research investigated the influence of functional training treatments on Wushu athletes' coordination abilities (Chen, 2020). Both male and female athletes improved significantly in results from the hexagonal jump test when subjected to equal training environments, durations, and loads. This study supports the hexagonal leap as a useful tool for measuring Wushu athletes' coordination abilities. While doing high-velocity leaps in various directions, participants must retain heightened sensitivity and adapt rapidly to bodily instability or abrupt exigencies, successfully reflecting Wushu players' physical aptitude and rhythmicity (Chen, 2020). As a result, the analysis of the chosen research concludes that functional training is a notable avenue for improving the leaping prowess required for Wushu. Functional training dramatically

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improves the critical aspects of Wushu competition, such as jump altitude, velocity, and aerial technique. This systematic analysis supports prior studies that suggests functional training might increase jumping proficiency in athletes from various sports (Elbadry, 2014; Resende Neto et al., 2018; Teixeira et al., 2020; Usgu et al., 2020).

The findings of this systematic review could benefit Wushu coaches and practitioners. These findings enable them to create focused exercises, reducing injury risks and improving movement fineness. This review also shows some gaps related to this study: (1) intervention gap, (2) population gap, and (3) outcome gap.

(1) Intervention Gap

The system review found 12 studies involved moderate in-intensity functional training for Wushu athletes, two involved low-intensity functional training, and two used low-to-moderate-intensity excessive functional training. However, an intervention gap was established: no research focusing on the influence of HIFT training on Wushu athletes. Due to limited research, Wushu athletes have benefited from low or moderate-intensity functional training, but HIFT training has yet to be given attention. Previous studies have shown that HIFT can help improve the performance of athletes in other sports, such as gymnastics (Zhu, 2023), volleyball (Bozdogan, 2021), taekwondo (Mischenko et al., 2021), judo (Avetisyan et al., 2022), and wrestling (Yuksel et al., 2019). Therefore, exploring the high-intensity functional training of Wushu athletes is necessary.

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(2) Population Gap

In this systematic review, sixteen articles focused on Wushu athletes, and four focused on college Wushu athletes. However, a population gap has been discovered: research needs to focus on the impact of HIFT training on Wushu athletes, especially college Wushu routine athletes. The age of university Wushu routine athletes is generally between 18 and 22 years old, with their bodies gradually maturing and possessing a certain level of Wushu routine techniques and theoretical knowledge. Previous research has indicated that functional training can assist Wushu athletes enhance their athletic performance, but research on college Wushu routine athletes is limited (Fan, 2020; Sun, 2020; Zhang et al., 2021; Zhang, 2021).

(3) Outcome Gap

Only four studies related to Wushu routines involve testing jumping movements. However, only two of the jump tests in the study were Wushu jump technique tests. Both studies lack research on contralateral Somersault and high difficulty jumping techniques at 540 ° or even 720 °. Scholars and experts have little research on "how to improve the speed of rotation" and "how to increase the number of degrees of rotation" regarding the difficulty of jumping vertical rotation (Jiao, 2018). Sports performance is the key factor for the survival and development of competitive athletes, coaches, and sports teams, and it is also the core of competitive sports. The completion of difficult jumping movements such as Outward Leg Swing in Flight at 540° or 720° and Whirlwind Kick at 540° or 720° directly determines the abilities of Wushu routine athletes (Wei, 2015). There is limited evidence to support the claim that functional training helps enhance Wushu athletes' leaping difficulty movements. Therefore, studying the functional training of Wushu jumping difficulty movements performance

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is crucial.

2.8 Theoretical Framework

This section mainly focuses on two aspects: (1) Introduction to the High-intensity Functional Training Theory and (2) Introduced the theory of internal and external training load.

(1) High-Intensity Functional Training Theory

The high-intensity functional training model explains how to improve athletes' overall physical fitness and athletic abilities through comprehensive training methods (see Figure 2.1) (Feito et al., 2018). HIFT includes two main components: mechanical and metabolic enhancement and neural and psychological adaptation.

a. Mechanical and Metabolic Enhancement

HIFT promotes muscle fibre thickening and protein synthesis through high-intensity repetitive movements and load training, increasing muscle contraction strength. In the early stages of high-intensity training, the increase in muscle strength mainly comes from adapting the nervous system, including the recruitment of more exercise units (Bozdogan, 2021). In addition, HIFT increases metabolic rate through high-intensity interval training, enabling it to utilise energy during training and competition more effectively (Feito et al., 2018).

b. Neurological and Psychological Adaptation

HIFT enhances the central nervous system's ability to control muscles and improves the coordination of motor units through compound movements involving multiple joints and planes (Feito et al., 2018). At the same time, training on unstable surfaces and functional movements enhances athletes' proprioception and coordination, enhancing their balance and control abilities during exercise (Ben-Zeev & Okun, 2021). The diversified training content of HIFT promotes the acquisition and improvement of athletes' skills (Rivas-Campo et al., 2023). It enhances neuromuscular control ability and motor memory through complex and varied training modes. In addition, high-intensity training poses psychological and physiological challenges to athletes, enhancing their focus and reaction speed (Rivas-Campo et al., 2022).

Through the combined effects of mechanical and metabolic enhancement and neural and psychological adaptation, HIFT significantly enhances athletes' physical adaptability. This adaptability is reflected in improving muscle strength and metabolic rate, neuromuscular control, skill acquisition, and psychological adaptability. Ultimately, these adaptive changes will translate into a comprehensive improvement in athletic performance.

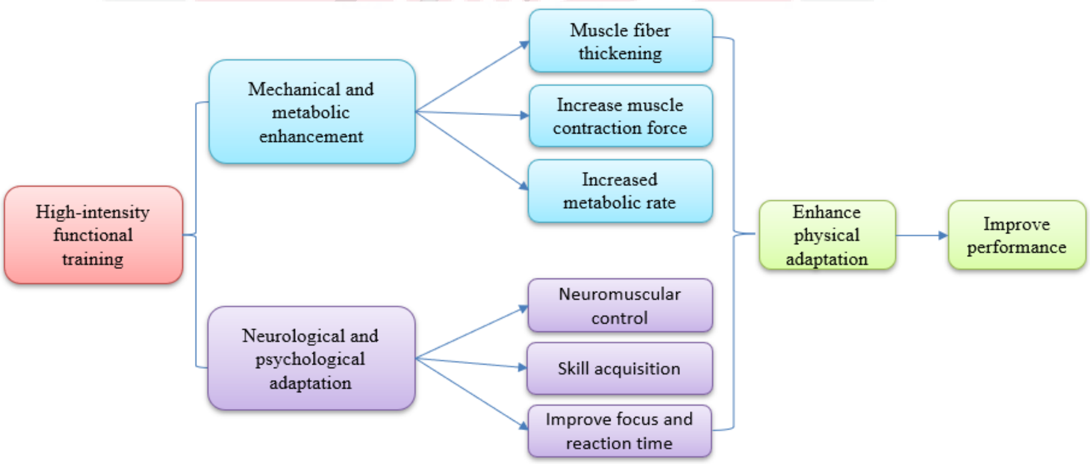

Figure 2.1 : Theoretical Framework of the HIFT Training (Feito et al., 2018)

(2) The Theory of Internal and External Training Load

The concepts of internal and external training loads were first introduced at the 8th Annual Congress of the European College of Sport Science, held in Salzburg, Austria, in 2003. Although these concepts were initially introduced, they were not extensively discussed then. Impellizzeri et al. (2019) further developed this theoretical framework and provided definitions for internal and external training loads (see Figure 2.2).

External load is determined by the type, time, intensity, and frequency of physical training. In contrast, the concept of internal load encompasses all the psychophysiological responses that occur during the exercises prescribed by the coach. The experience of internal load during a specific external load may vary among athletes, influenced by specific factors between and within athletes (Impellizzeri et al., 2023). Factors that can lead to varying internal loads despite similar external loads include individual characteristics, training status, nutrition, health environment, psychological state, and genetics. Therefore, the training outcomes of athletes with similar external loads may show improvement, no change, or decrement.

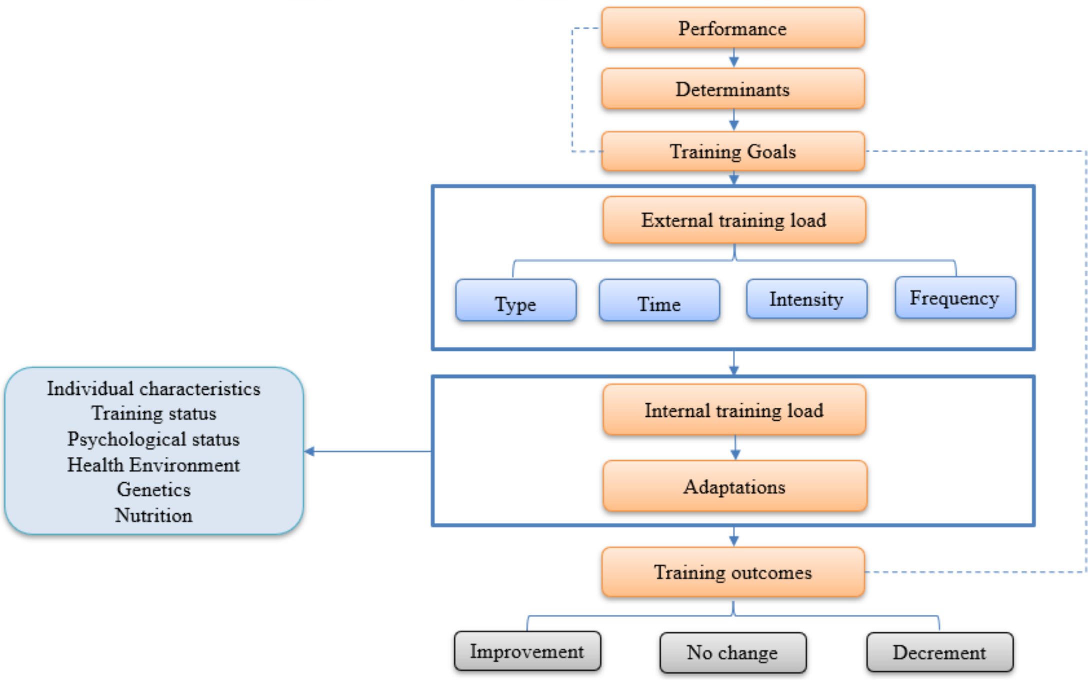

Figure 2.2 : Theoretical Framework of the Training Process
(Impellizzeri et al., 2019)

2.9 Conceptual Framework

The study's conceptual framework is based on the Training Process Model (Impellizzeri et al., 2019) and the HIFT Training Theory (Feito et al., 2018). This framework designs a structure that links HIFT training, physical fitness, and jumping difficulty movements. The effective utilisation of internal and external loads helps to determine the athlete's response to high-intensity functional training programs, guiding the psychological and physiological reactions athletes produce during HIFT training, and affecting the time, intensity, and frequency of HIFT training.

For the experimental group, the HIFT Training Theory emphasises the complex interactions between mechanical, metabolic, neurological, and psychological adaptations that affect physical activity and performance, comprehensively improving athletes' jumping ability. Developing strength and power ensures that athletes can generate maximum strength and explosiveness during take-off. Speed enhancement enables athletes to react swiftly and precisely execute movements, while improved endurance ensures sustained performance in aerial manoeuvres and effectively mitigates fatigue. Increased flexibility allows athletes to exhibit a greater range of motion during take-off, rendering movements more aesthetically pleasing and elevating the quality of execution. Consequently, athletes achieve consistent and efficient jumping performance.

In contrast, the control group follows a standard training program, which focuses on basic and routine exercises without incorporating the high-intensity, multi-faceted stimuli provided by HIFT. Based on the Internal and External Training Loads Model, the external load (e.g., type, intensity, and frequency of training) in the control group is expected to remain constant, with limited variation in the internal load due to reduced complexity and intensity of the training program. As a result, the control group is unlikely to experience the same degree of adaptation in strength, power, endurance, speed, and flexibility. While the control group may show minimal improvements due to regular practice, the changes are expected to be less significant than those observed in the experimental group.

By incorporating both experimental and control groups into the conceptual framework, this study provides a comprehensive perspective on the unique benefits of HIFT training compared to standard training methods. Figure 2.3 illustrates the complete framework, highlighting how internal and external loads, influenced by the HIFT Training Theory, interact within the context of Chinese Wushu.

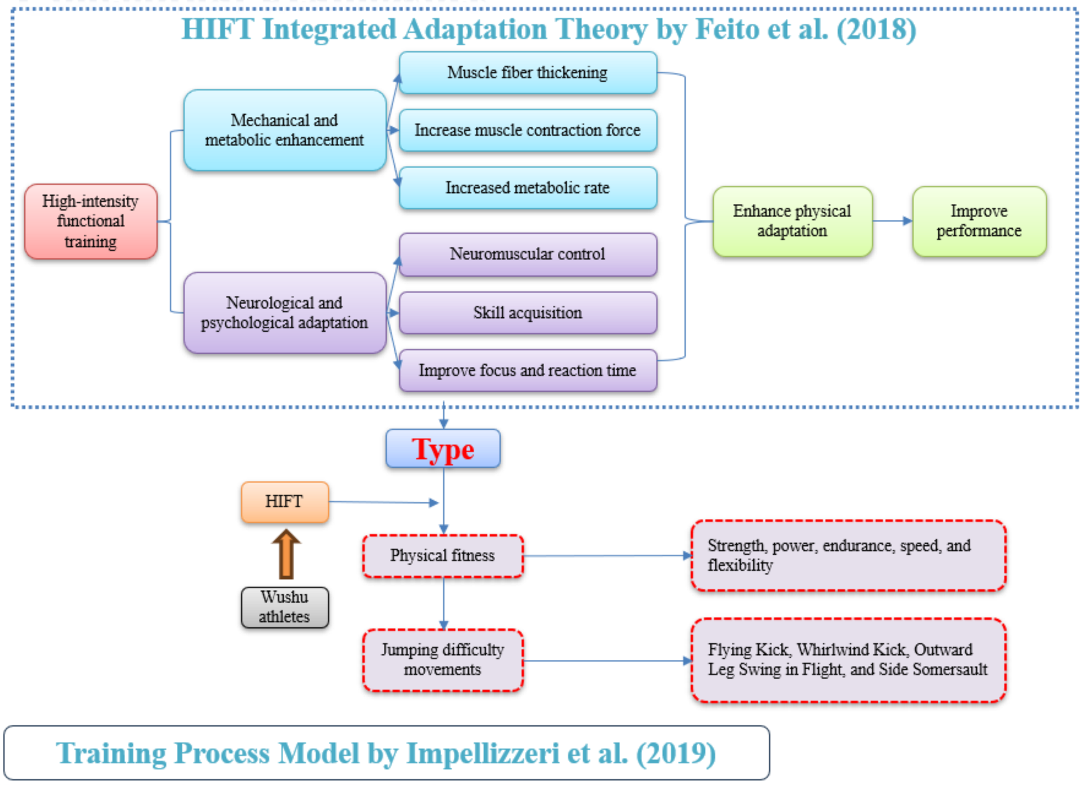

Figure 2.3 : Conceptual Framework

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter introduces the study's methodology section, including study design, cluster selection and randomisation, study location, participants and sampling methods, study instructions, validation of method, intervention, control of extraneous variable, pilot study, data collection procedures, and statistical analysis.

3.2 Study Design

This study employed an experimental design featuring a pre-test post-test structure and a cluster-randomised controlled trial (cRCT). Cluster randomised trials involve randomly dividing groups or clusters of individuals (rather than individuals themselves) into intervention and control groups, with outcomes measured at the individual level within these clusters (Spieth et al., 2016). The concept of whole-group randomisation was first discussed by Lindquist in 1940 (Lindquist, 2023). Since then, cRCTs have become increasingly common in research, particularly when randomisation of entire groups such as schools, workplaces, or teams is necessary (Offorha et al., 2023). The primary advantage of cRCTs is their capacity to evaluate interventions that target entire clusters rather than individuals, effectively minimising contamination between intervention and control groups (Offorha et al., 2023) This design is particularly suitable for studying the effects of HIFT training on the physical fitness and jumping difficulty movements of college male Wushu routine athletes. By randomising two clusters—Changan and Yuhua districts in Hebei Province—this study ensured that participants within the same cluster shared similar training

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environments and external influences. In the present research, the intervention development component of the researchers used Greg Glassman's (2010) "CrossFit training guide" to create a HIFT program based on the features of Wushu routines. HIFT combines high-intensity, multi-joint, functional movements that simultaneously target strength, power, endurance, speed, and flexibility. It emphasizes efficiency, variability, and the integration of sport-specific skills. In contrast, standard training focuses on traditional strength and endurance exercises, often performed in isolation with longer rest periods.

This study's experimental phase is 12 weeks, three sessions each week. The training session lasts 90 minutes and includes 60 minutes of physical exercise and 30 minutes of focused technical instruction. The two groups' specialist skills training material is identical, except for the physical training component. Furthermore, the control group receives particular training content from the school's normal training plan (see Appendix D for details). The dependent variables in this study will include physical fitness (strength, power, speed, endurance, and flexibility) and jumping difficulty movements (Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault). The dependent variable was evaluated three times during the intervention: at baseline before the experimental intervention, at post-test 1 after 6 weeks, and at post-test 2 after 12 weeks. Finally, statistical analysis was applied to the three test outcomes. To enhance study validity, several measures were taken: the training protocol was evaluated by six sports experts for content validity (CVI results indicated high validity), and all participants provided informed consent. Additionally, this study was registered at ClinicalTrials.gov (ID: NCT06181487), ensuring transparency and adherence to international research standards.

3.3 Cluster Selection and Randomisation

The eligibility criteria for selecting clusters in this study include universities with many Wushu routine athletes. After numbering sixteen universities in Hebei Province from 1 to 16, a random number generator (Excel) was used to generate two random integers that cannot be the same. This represents a randomly selected university number. The randomisation process was carried out independently by other scholars not involved in this study. Then, athletes were randomly allocated to two training venues and split into experimental and control groups. The experimental group got HIFT training, whereas the control group received standard training.

Figure 3.1 shows the above research framework, showing the impact of high-intensity functional training on Wushu routine athletes' physical fitness and jumping difficulty movements.

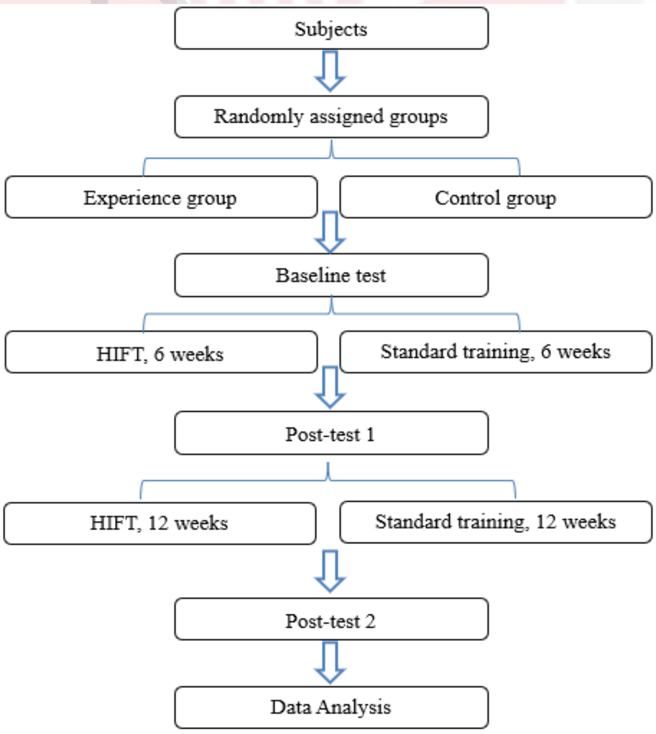

Figure 3.1 : Research Framework

3.4 Study Location

This study was conducted in Hebei Province, China. This study recruited two universities in Hebei Province with many male Wushu routine athletes. After field investigations by researchers, it was found that these two universities are the Hebei Institute of Physical Education and Hebei Normal College. A national second-level athlete certificate is prerequisite for admission to these two universities. It is worth noting that these athletes have performed well in the Wushu routine competitions in Hebei Province and are eligible to participate in the national Wushu routine competitions. Therefore, these male college athletes can represent Chinese Wushu routine athletes.

3.5 Participants and Sampling Methods

This section mainly includes participants and sampling, sample size, criteria for participants, and sampling process.

3.5.1 Participants and Sampling

This study's target participants are male Wushu routine athletes currently studying at two designated universities in Hebei Province, China. The colleges include Hebei Institute of Physical Education and Hebei Normal College. Potential participants were screened, and those with sports injuries were excluded.

3.5.2 Sample Size

G*Power 3.1 is a statistical power analysis software used to calculate the study sample size. This study determined the effectiveness of research interventions based on previous studies (Appendix B). The researchers selected the minimum effect size of sit-and-reach (0.20) (Ambrozy et al., 2022). This study was divided into experimental and control groups, with three repeated tests: baseline, post-test 1, and post-test 2. The sample size is calculated using an F-test analysis of variance for repeated measurements between interactions. In addition, set α to 0.05 and power to 0.8. The sample size was estimated to be 42 participants. The calculation process is shown in Appendix B.

Compared to standard randomised controlled trials, cRCT typically requires a larger sample size (Pandis, 2012). The adequate sample size is the product of the design effect (DE), and the standard RCT calculates the sample size (Ribeiro et al., 2018). Usually, human studies' intra-cluster correlation coefficient (ICC) ranges from 0.01 to 0.02 (Kang, 2021). Previous studies used the ICC at 0.01 (Musca et al., 2011). Due to the use of cRCT in this study, there were two clusters with 21 participants in each group. Therefore, the sample size calculation for this study is shown in Figure 3.2.

Equation 1: **DE=l + p(m-1)**

Equation 2: **ESS=DE*mk**

Where m is the number of participants in the cluster, k is the number of cluster, mk is the total number of participants in the cluster study, ESS effective sample size, DE is design effect, p is intra cluster correlation coefficient (ICC). Therefore, in this study, the effective sample size was calculated as follows:

ESS= [1+0.01*(21-1)] * 42 =50.40

Figure 3.2 : The Equation for Calculation Sample Size

Due to a dropout rate of 20% of the total sample size (Rutterford, 2015), this study added 18 participants. Because there were two groups, the researchers added 9 participants to each group. Therefore, the final sample size for this study was 60 participants, with 30 participants in each group.

3.5.3 Criteria for Participants

Participants were recruited based on the researchers' inclusion and exclusion criteria. The inclusion criteria for this study are as follows:

1) Male Wushu routine athletes (aged 18-22).
2) At least three years of experience in training Wushu routines.
3) No history of recent surgery.
4) No experience in HIFT training.

The exclusion criteria of this study are as follows:

1) Athletes with physical surgery.
2) Have HIFT experience.

3.5.4 Sampling Process

This study conforms to the "Consolidated Standards of Reporting Trials" guiding principle of cluster experiments (Jung & Kim, 2014). This study recruited 70 male Wushu routine athletes during recruitment (refer to Figure 3.3). 10 participants who did not meet the inclusion criteria were excluded. Therefore, only 60 eligible participants were assigned to the experimental group (n=30) and the control group (n=30). All participants voluntarily consented to the experiment and signed a written informed consent form. During the experimental intervention period, all participants participated in the training throughout the entire process. Therefore, there are 60 valid datasets available for final statistical analysis.

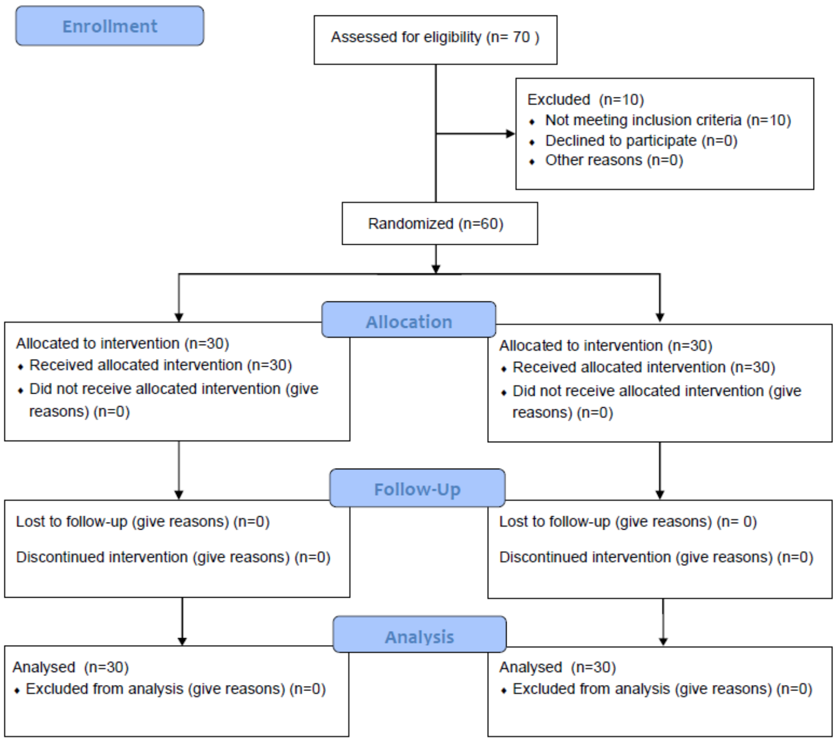

Figure 3.3 : CONSORT Diagram
(Source: Spieth et al., 2016)

3.6 Study Instruments

This study only involves on-site testing of one instrument. It focuses on variable testing and instrumentation, divided into (1) physical fitness and (2) jumping difficulty movements testing. The scoring for jumping difficulty movements was based on the official competition rules of the Chinese Wushu Association (2021). Each movement was evaluated out of 100 points across four dimensions: execution quality (40 points), technical difficulty (30 points), aesthetic and fluidity (20 points), and landing stability (10 points). Three independent experts assessed each movement using video analysis captured by an M120 high-speed camera, and the final score was determined as the average of the three ratings to minimize subjectivity. The reliability of this scoring system has been validated in previous studies and conforms to standardized testing protocols. A comprehensive description is provided in Appendix F.

Table 3.1 : Instruments for Measuring Physical Fitness

Variable	Test	Instrument	Unit
● Strength	Push-ups	Stopwatch	Numbers
● Power	Standing long jump	Measuring tape	Centimetres
● Endurance	Jumping rope	Stopwatch	Numbers
● Speed	Sprint 30 m	Stopwatch	Seconds
● Flexibility	Sit-and-reach	Sit and reach test tool	Centimetres

Table 3.2 : Instruments for Measuring Jumping Difficulty Movements

Variable	Test Method	Instrument	Unit
● Flying Kick	3 Experts	M120 high-speed camera	Scores
● Whirlwind Kick	3 Experts	M120 high-speed camera	Scores
● Outward Leg Swing in Flight	3 Experts	M120 high-speed camera	Scores
● Side Somersault	3 Experts	M120 high-speed camera	Scores

3.7 Validation of Method

The effectiveness of testing is crucial for researchers when choosing any research tool (Ary et al., 2018). Effectiveness reflects the validity and reliability of the research process. The test of jumping difficulty movements in Wushu routines is a standardised test conducted following the competition rules of the Chinese Wushu Association (Han et al., 2021). Each jumping difficulty movement score is 100 points, and three experts rate the athletes based on their on-site technical performance. Table 3.1 discusses physical fitness testing methods and instruments. Table 3.2 discusses jumping difficulty movements testing methods and instruments. This study selected six field experts based on their physical training experience to establish an expert group (see

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Table 3.3 for expert details) to evaluate the effectiveness of the research method content. Therefore, all tests are reliable and effective.

3.7.1 Face Validity

Face validity assesses whether the instrument appears on the surface to capture the intended concepts effectively (Surucu & Maslakci, 2020). Once the research instrument was finalised, it was reviewed in detail by an oversight committee comprising experts in the field. The expert committee scrutinised each item of the research instrument and provided detailed feedback. Based on the expert feedback, necessary corrections and improvements were made to the research instrument to improve its face and overall validity. It is worth mentioning that all the research instruments used in this study have demonstrated strong validity in previous related studies. The physical fitness test protocol and the jumping difficulty movements tests were selected based on the test recommended by the Chinese Wushu Association (Chinese Wushu Association, 2012; Chinese Wushu Association, 2021).

3.7.2 Content Validity

Content validity is critical in ensuring that a research instrument provides comprehensive coverage of the concepts and domains to be measured. It is usually established through review by a panel of experts or scholars (Yusoff, 2019). To assess the content validity of the research instrument, the researcher selected six experts with extensive experience and expertise in training and related fields. These experts included two professors, two associate professors, and two sports coaches (see Table 3.3 for details of the experts). The composition of the expert panel ensured that the assessment was diverse and specialised. The experts evaluated the research

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instruments using a 4-point scale (1: not relevant; 2: somewhat relevant; 3: fairly relevant; 4: highly relevant) to determine the content validity of the questionnaires (details are provided in Appendix E, Table 1). In addition, an open-ended question about the intervention and research instrument was included to gather expert opinions and suggestions for further refinement.

The validity of the instrument content was measured using the Item Content Validity Index (I-CVI). The relevance of each item was determined by calculating the I-CVI value based on the Kappa correction factor (McHugh, 2012). The criteria for interpreting the Kappa values are as follows: kappa ≤ 0 indicates no consistency, 0.01-0.20 shows very little to slight consistency, 0.21–0.40 shows fair agreement, 0.41-0.60 shows moderate agreement, 0.61-0.80 shows high agreement and 0.81–1.00 shows almost perfect agreement. The acceptable limit for the I-CVI in this study was 0.78, as Yusoff (2019) recommended. After evaluation of the research interventions and instruments by six experts, the results showed that the content validity of all the items was within the acceptable range, proving the high relevance and clarity of consistency of the research instruments (physical fitness: I-CVI = 0.833–1.000, Kappa = 0.816–1.000; jumping difficulty movement: I-CVI = 1.000, Kappa = 0.816–1.000; jumping difficulty movement: I-CVI = 1.000, Kappa = 1.000). Specific results are presented in Table 3.4. All items met acceptable thresholds, further indicating that the testing procedure had good content validity.

Table 3.3 : Personal Details of Content Validity of Instrument Experts

Organization	Degree	Area for research
● Chengdu Sport University	Professor	The theory and practice of wushu teaching and training
● Guangxi Normal University	Professor	Sports Science
● Henan University	Assistant Professor	Sports Science
● Chengdu Sport University	Associate Professor	Physical Education
● Hebei Sport University	Wushu Coach	Wushu Education
● Nanchong Sports Club	Wushu Coach	Physical Education

Table 3.4 : Content Validity Instruments Based on Experts

Variable	Measurement Method	Number in agreement	relevance		Number in agreement	Clarity	
			I-CVI	KAPPA		I-CVI	KAPPA
▪ **Strength**	Push-ups	5	0.833	0.816	6	1.000	1.000
▪ **Power**	Standing long jump	6	1.000	1.000	6	1.000	1.000
▪ **Endurance**	Jumping rope	5	0.833	0.816	5	0.833	0.816
▪ **Speed**	Sprint 30 m	6	1.000	1.000	6	1.000	1.000
▪ **Flexibility**	Sit-and-reach	5	0.833	0.816	5	0.833	0.816
▪ **Jumping difficulty movements**	Flying Kick	6	1.000	1.000	6	1.000	1.000
	Whirl Wind Kick	6	1.000	1.000	6	1.000	1.000
	Outward Leg Swing in Flight	6	1.000	1.000	6	1.000	1.000
	Side Somersault	6	1.000	1.000	6	1.000	1.000

Noted: 0.78 as the limit of acceptability for I-CVI (Yusoff, 2019); Kappa, values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41-0.60 as moderate, 0.61–0.80 as substantial, and 0 .81-1 .00 as almost perfect agreement (McHugh, 2012)

3.8 Intervention

In this study, researchers designed a high-intensity functional training program focused on Wushu routines, with intervention designs referencing Greg Glassman's (2010) "CrossFit Training Guidelines" (Glassman, 2010). A panel of experts evaluated the intervention protocol.

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3.8.1 Design of 12 Weeks High-Intensity Functional Training Program

The framework of the weekly high-intensity functional training plan for Wushu routine training is based on Greg Glassman's book CrossFit Level 1 Training Guide (Glassman, 2010). This training plan includes three stages: high-intensity functional training Adaptation Stage: Focused on proper movement patterns and gradual adaptation to high-intensity demands; High-intensity functional training Enhancement Stage: Increased intensity and reduced rest intervals to maximise fitness and sport-specific skills; and high-intensity functional training Consolidation Stage: Reinforced gains through competition-specific exercises with minimal rest intervals. The high-intensity functional training program is detailed in Appendix D.

The experimental group implemented HIFT, emphasizing multi-joint functional movements such as jump rope, clean and jerk, and kicking drills, combined with sport-specific techniques. Training was conducted at high intensity (up to 90% HRmax) with short rest intervals (30 – 10 seconds) between sets, simulating high-intensity competition scenarios (Chizewski et al., 2021). Advantages of HIFT: HIFT targets multiple fitness dimensions simultaneously, including strength, power, endurance, speed, and flexibility. The exercises mimic competitive scenarios, enhancing both physical and technical performance in Wushu. The high-intensity structure optimizes session duration. Limitations of HIFT: The initial phase requires athletes to adapt to the unique demands of HIFT, which may delay progress.

The control group engaged in traditional strength and endurance training, including bench press, barbell curl, and squats, primarily targeting isolated muscle groups. Training intensity was moderate (60%-70% HRmax), with relatively longer rest intervals (60 seconds) between sets (Kapsis et al., 2022). Advantages of standard training: Moderate intensity minimizes the risk of overtraining, making it suitable for extended use. Isolated exercises allow for focused improvement of specific muscle groups. Limitations of standard training: Does not replicate sport-specific demands, reducing carryover effects to Wushu performance. Isolated and moderate-intensity exercises may result in slower overall improvement compared to HIFT.

Therefore, this study adopts a high-intensity functional training program as the intervention method to enhance the physical fitness and jumping difficulty performance of male Wushu routine athletes.

3.8.2 Frequency, Length, and Time

Based on the researchers' two systematic reviews (Wang et al., 2023, 2024), both the experimental and control groups in this study followed a training frequency of three sessions per week, each lasting 60 minutes, over a 12-week period.

The experimental group engaged in High-Intensity Functional Training (HIFT) at high intensity (up to 90% HRmax), while the control group performed moderate-intensity training (60%-70% HRmax). The HIFT program was designed as a single-dose structure to ensure consistency with the study objectives. The selection of high intensity (90% HRmax) was supported by evidence demonstrating its efficacy in improving physical fitness and performance within 12 weeks (Feito et al., 2018; Osipov et al., 2019).

The systematic review by Wang et al. (2023) has shown that an 8–12 weeks duration is sufficient to observe significant improvements in physical fitness components and sport-specific performance following high-intensity functional training (Feito et al., 2018; Osipov et al., 2019). Additionally, the 12-week period aligns well with the athletes' training schedules and academic semesters, ensuring feasibility without posing a risk of overtraining. The chosen duration is consistent with previous systematic reviews, supporting its appropriateness for achieving the study's objectives.

The intervention included assessments at 6 weeks (Post-test 1) and 12 weeks (Post-test 2) to evaluate the short-term and cumulative effects of HIFT. The 6-week assessment aimed to capture early adaptations, such as initial changes in physical fitness, while the 12-week assessment focused on long-term impacts, including comprehensive improvements in physical fitness and jumping difficulty movements. This phased assessment approach aligns with physiological adaptation timelines and ensures the intervention duration matches the research goals of enhancing physical fitness and sport-specific performance. For more details, refer to Table 3.5.

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Table 3.5 : Information on Training Intervention

Experimental group	Intensity	Sets/reps	Rest (sets/reps)	Control group	Intensity	Sets/reps	Rest (sets/reps)
Warm up (10 min)							
Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s
Physical training (40 min)							
Jumping rope. Clean and jerk. Jumping Whirlwind Kick. Romanian deadlifts. Jumping Outward Leg Swing in Flight. Single-leg squat. (Shalmanov & Lukunina, 2020; Yu, 2021; Glassman, 2010)	90% HRmax (Glassman, 2010)	AMRAP (Glassman, 2010)	90s/10s (Glassman, 2010)	Bench press. Deadlifts. Barbell Biceps Curl. Barbell Squat. Sitting position with weight-bearing knee extension. Calf raises. (Su, 2015)	60%-70% HRmax (Su, 2015)	3 sets/ 8-10 reps (Su, 2015)	60s (Su, 2015)
Cool down (10 min)							
Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s

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3.8.3 Validity of Interventions

The Content Effectiveness Index (l-CVI) is a statistical method used to evaluate the effectiveness of the study's intervention content. A panel of six experts screened the content. Please refer to Table 3.3 for detailed information on experts. For detailed validation information on expert evaluation of intervention content, please refer to Table 3.6. Regarding the relevance of intervention content, all projects provided an acceptable range of effectiveness (I-CVI = 0.833–1.000, Kappa = 0.816–1.000). Regarding the clarity of intervention content, all projects provided an acceptable range of effectiveness (I-CVI = 0.833–1.000, Kappa = 0.816–1.000). Therefore, this intervention project has good content effectiveness.

Table 3.6 : Relevancy and Clarity Agreement of the Intervention Items

Type	Number in agreement	Relevance		Number in agreement	Clarity	
		I-CVI	KAPPA		I-CVI	KAPPA
▪ **Overall evaluation of the program**	6	1.000	1.000	6	1.000	1.000
▪ **Duration**	6	1.000	1.000	6	1.000	1.000
▪ **Frequency**	6	1.000	1.000	6	1.000	1.000
▪ **Intensity**	6	1.000	1.000	6	1.000	1.000
▪ **Time**	6	1.000	1.000	6	1.000	1.000
▪ **Content of Warm- up**	6	1.000	1.000	6	1.000	1.000
▪ **Content of Physical training**	6	1.000	1.000	6	1.000	1.000
▪ **Content of Cool down**	6	1.000	1.000	6	1.000	1.000
▪ **Sets and reps**	6	1.000	1.000	6	1.000	1.000
▪ **Rest time**	5	0.833	0.816	5	0.833	0.816

Noted: 0.78 as the limit of acceptability for I-CVI (Yusoff, 2019)；Kappa, values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41-0.60 as moderate, 0.61–0.80 as substantial, and 0 .81-1 .00 as almost perfect agreement (McHugh, 2012).

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3.9 Control of Extraneous Variables

External variables refer to factors that may interfere with or affect research results and lead to research bias (Belkhode et al., 2021), which is not within the researcher's control. Therefore, researchers must take action to reduce the impact of external variables. This study uses the following methods to control external variables to make the experimental results more reliable.

3.9.1 Control of Environmental Factors

This study includes physical exercise, Wushu routine jumping exercises, and field tests. Weather changes such as rain may affect the intervention process and testing results, making it difficult for participants to adhere to the training plan or testing as agreed. To overcome this issue, this study arranged for participants to undergo training and testing in the gym during the intervention period. Therefore, environmental factors have a relatively small effect in this study.

3.9.2 Control of Test Protocols

The testing protocol is a specific method for evaluating the training effectiveness of participants, which significantly affects the accuracy of testing data. This study's intervention coaches and participants strictly follow standardised testing procedures, such as informing participants of the testing process and precautions before testing. At the same time, the intervention coach checked all the testing instruments. During the data collection process of this study, the experimental group and the control group used the same testing instruments to evaluate the participants and avoid irrelevant factors affecting the accuracy of the test data.

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3.9.3 Control of the Preparation of Participants before Tests

To minimise variability in test performance, researchers provided participants with detailed explanations of the testing procedures and considerations. Clear communication ensured participants fully understood the test's purpose and their responsibilities, fostering cooperation and compliance. Participants were instructed to follow strict pretest behavioural guidelines, such as avoiding strenuous physical activity and maintaining a balanced diet 48 hours before testing (da Silva, 2022). Caffeine and alcohol consumption were prohibited two days before the test, and the testing sequence and recovery time between tests were standardised to minimise fatigue and interference effects.

3.9.4 Control of the Intervention Program

Before the experiment, this study communicated with the coaches in the experimental and control groups, explaining the HIFT training plan, physical fitness, and jumping difficulty movements. Ensure that both groups of participants undergo the same training process, with the experimental group based on HIFT training programs and the control group receiving standard training programs. The experimental and control groups have one coach and one assistant coach. Both coaches are college Wushu coaches with professional teaching experience and knowledge of physical training. All assistant coaches hold physical education coach qualifications and Wushu referee certificates.

3.9.5 Control of Participants and Covariates

During this study, all participants had to sign an informed consent form and promise to strictly adhere to the established training plan and not participate in any other form of physical exercise (see Appendix C). Coaches monitored participants throughout the intervention to ensure adherence. Beyond these measures, additional covariate data were collected to account for potential confounding factors. The participants of this study are male college Wushu routine athletes. They are professional Wushu athletes and plan to participate in the selection competition of the national Wushu team in China. The coach tells the participants what to do. They strictly follow the coach's instructions because if they don't listen the coach's arrangements, they may be kicked out of the Wushu team. All participants in the study have at least three years of professional training experience in Wushu routines and have reached the national second level athletes. Wushu routine training requires high energy for athletes, and participants need sufficient rest to maintain high-intensity training in Wushu. If participants engage in additional physical activities, it can affect their athletic performance. All the Wushu athletes understand the severity of this additional training.

To control dietary and daily behavioural activities, participants were instructed to maintain consistent eating habits, guided by recommendations based on previous studies (Chinese DRIs, 2023; McDonough et al., 2022; Wassenaar et al., 2021). These recommendations included dietary energy intake aligned with different levels of physical activity. Participants also committed to avoiding long periods of sedentary behaviour, excessive use of electronic devices, and activities like deskwork or studying that might affect posture and performance. Data on dietary compliance, daily activities, and adherence to these guidelines were documented, and statistical analyses confirmed no significant differences between groups during the intervention period. Detailed records of dietary recommendations, energy intake guidelines, and activity monitoring are provided in Appendix L, including referenced literature to substantiate dietary controls. This additional data collection and documentation strengthen the study's rigor and credibility by addressing group equivalency and ensuring that no confounding factors influenced the outcomes.

3.10 Pilot Study

This study conducted a two-week preliminary study before the official implementation of cRCT to evaluate the effectiveness of intervention design, participant recruitment, and test results. This study selected 20 male Wushu routine athletes recruited from universities. The pilot study was held at the Sports Centre of Hebei College of Physical Education. Randomly divide participants into an experimental group (n=10) and a control group (n=10). The pilot study was conducted twice a week and lasted for two weeks. They strictly followed the intervention measures and tested all the instruments designed in this study.

3.10.1 Reliability of the Methods

Reliability measures the extent to which instruments and procedures produce consistent results in repeated trials (Surucu & Maslakci, 2020). In social research, reliability is usually assessed in three ways: test-retest, alternative forms, and internal consistency (Surucu & Maslakci, 2020). In this study, researchers chose test-retest as the primary method to ensure consistency and reliability of the measurements. Test-retest reliability assesses the consistency of results by administering the same test to the same group of participants at different points in time. This method is simple yet

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effective in visualising the stability and reliability of a measurement tool over time. In this study, researchers conducted multiple retests of selected physical fitness and jumping difficulty movements to assess the reliability of these dependent variables. To quantify the reliability of the test-retests, researchers analysed them using the ICC, a statistical index widely used to assess measurement consistency, with values ranging from 0 to 1. According to Yusoff's, (2019) classification criteria, an ICC value of more than 0.90 indicates "excellent" reliability; ICC values between 0.75 and 0.90 indicate "good" reliability; ICC values between 0.50 and 0.75 indicate "moderate" reliability; and ICC values less than 0.50 indicate "poor" reliability. ICC values of less than 0.50 indicate "poor" reliability. In this study, the ICC values for all instruments and measurement procedures were within the acceptable range, and the detailed results are shown in Appendix I, Table 1.

3.10.1.1 Physical Fitness Variables

The selected fitness components were strength (ICC = 0.973), power (ICC = 0.982), endurance (ICC = 0.846), speed (ICC = 0.936), and flexibility (ICC = 0.959). The test-retest reliabilities for physical fitness ranged from 0.846 to 0.982, indicating that the testing program is highly reliable and appropriately reflects the fitness level of local young male Wushu routine athletes (see Table 1 in Appendix I for details).

3.10.1.2 Jumping Difficulty Movements Variables

Jumping difficulty movements include Flying Kick (ICC = 0.958), Whirlwind Kick (ICC = 0.952), Outward Leg Swing in Flight (ICC = 0.942), and Side Somersault (ICC = 0.938). These values indicate that the jumping difficulty movements test is very effective in evaluating athletes' jumping skill performance, and that these instruments can provide an objective diagnosis of the skill level of Wushu routine athletes (see Table 1 in Appendix L for details).

3.11 Data Collection Procedures

The stages of collecting data are as follows: (1) Request for permission; (2) Data collection.

3.11.1 Request for Permission

The experimental protocol for this study has been registered with the Clinical Trials Government Protocol and the Results System Receipt (Clinical Trials. gov ID: NCT06181487; Appendix A). Before data collection, it has also been reviewed and approved by the Ethics Committee of Universiti Putra Malaysia (reference number: JKEUPM-2023-1359) and the Medical Ethics Committee of Zhejiang Dongfang Polytechnic, China (acceptance number: No.1041668, 24/11/2023). The Ethics Committee allows researchers to conduct participant intervention experiments (see approval letter in Appendix A).

3.11.2 Data Collection

The researcher was assisted by professional coaches from two universities in collecting all the data for this study. The testing program is divided into three stages. Firstly, before the intervention experiment, researchers explain the content and testing process of high-intensity functional training to the coaches and participants in charge of the intervention. During this period, baseline testing before intervention was conducted, including covariate data. Secondly, during the 12-week intervention

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process, coaches monitored the entire training plan and collected data in the sixth week. Finally, data collection was conducted on participants after a 12-week intervention experiment. It is worth noting that data collection was performed on the same day, with participants tested for jumping difficulty movements from 9 to 12 a.m. and tested for physical fitness from 3 to 6 p.m.

3.12 Data Analysis

This study tested the physical fitness (strength, power, endurance, speed, and flexibility) and jumping difficulty movements (Flying Kick, Whirl Wind Kick, Outward Leg Swing in Flight, Side Somersault) of two groups of participants before, during, and after the intervention. The data is recorded and entered into a computer Excel spreadsheet. Then, use SPSS software for statistical analysis. Firstly, summarise the descriptive features as mean ± standard deviation (SD). Secondly, the normality of the data is tested through the Shapiro-Wilk normality test. If the test data meets the normality condition, parameter statistical methods are used; otherwise, non-parameter statistical methods are used. Then, the Levene test was used to test the homogeneity of variance of the data between each group. Additionally, this study employed Analysis of Variance (ANOVA) to analyse normally distributed data and utilized the Generalized Estimating Equation (GEE) for data that did not conform to a normal distribution. Finally, the online tool (Effect Size Calculators, College of Colorado Springs) will calculate the intervention's effect size (d=0.2 for small, d=0.5 for medium, and d=0.8 for large).

The Statistical Package for Social Sciences (SPSS) Version 27 (IBM Company, United States) was used for data analysis. Before and after the experiment, the independent sample t-test was used for the transverse comparison analysis between groups, and the paired sample t-test was used for the longitudinal comparison within groups. P<0.05 *represents a significant difference; P<0.01 * *represents a very significant difference; P> 0.05, represents no significant difference. The statistical analysis of the research is shown in Table 3.7.

Table 3.7 : Research Hypothesis and Statistical Analysis

	Null Hypotheses	Statistical Analysis
H01	There was no significant difference in muscle strength between CG and EG among Wushu routine athletes.	ANOVA
H02	There was no significant difference in endurance between CG and EG among Wushu routine athletes.	ANOVA
H03	There was no significant difference in power between CG and EG Chinese college male Wushu routine athletes.	ANOVA
H04	There was no significant difference in speed between CG and EG among Wushu routine athletes.	GEE
H05	There was no significant difference in flexibility between CG and EG among Wushu routine athletes.	ANOVA
H06	There was no significant difference in Flying Kick between CG and EG among Wushu routine athletes.	ANOVA
H07	There was no significant difference in Whirlwind Kick between CG and EG among Wushu routine athletes.	ANOVA
H08	There was no significant difference in Outward Leg Swing in Flight between CG and EG among Wushu routine athletes.	ANOVA
H09	There was no significant difference in Side Somersault between CG and EG among Wushu routine athletes.	ANOVA

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CHAPTER 4

RESULTS

4.1 Introduction

This chapter introduces the impact of HIFT training on the physical fitness and jumping difficulty movements of Chinese College male Wushu routine athletes. Based on the experimental process and test results, descriptive results of athlete statistical characteristics in mean and standard deviation are reported. To test the effectiveness of high-intensity training, this chapter uses one-way analysis of variance (ANOVA) generalized estimation equation (GEE), and covariate analysis to address the hypotheses proposed in the research objectives.

4.2 Preliminary Tests of Statistical Assumption

This section evaluates the arithmetic expectations of data research techniques. Various types of statistical tests are used for quantitative and categorical data analysis. Parameter testing determines whether the obtained data satisfies the distribution normality assumptions and variance homogeneity. When the result data does not meet these two assumptions, non-parametric tests are used (Mann-Whitney U test) (Usman, 2016).

4.2.1 Normality Test

Normality testing is a crucial step in statistical analysis to verify whether data comes from a normal distribution. Parameter testing compares data that conforms to a normal distribution, while non-parametric methods compare data that does not conform to a normal distribution (Orcan, 2020). In this study, the researcher used the Shapiro-Wilk test to evaluate the normality of the data. The results showed that the demographic characteristics, physical fitness, and jumping difficulty of the two groups of participants mostly followed a normal distribution ($p>0.05$). However, some variables like age and speed do not follow a normal distribution ($p<0.05$). Please refer to Appendix H, Tables 1 to 3 for more information.

4.2.2 Homogeneity of Variance Test

The homogeneity of variance test is used to test whether the variances of each data group are equal. Homogeneity of variance is one of the critical assumptions in the analysis of variance method. The researcher uses Levene's test to evaluate the homogeneity of variance in each data group. The results showed no significant difference in the error variance between the experimental group (EG) and the control group (CG) in the baseline test, which is consistent with the hypothesis of homogeneity of variance. Please refer to Appendix G, Tables 1 to 3 for more information.

4.3 Demographic Characteristics

Before data analysis, independent sample t-tests were used to evaluate the homogeneity of demographic characteristics between the two groups (CG and EG), such as age, height, weight, and training experience. The results showed that there was no significant difference in age ($z=-0.30$; $P=0.77$), height ($t=-0.30$; $P=0.76$), weight ($t=-0.50$; $P=0.62$), and training experience ($t=0.59$; $P=0.56$) between the EG and CG. In other words, the two groups are homogeneous regarding demographic characteristics. More information can be found in Table 4.1. On the other hand, the age data did not fit the normal distribution. Thus, the Mann-Whitney U test was applied. The results also revealed no significant difference between the control and experimental respondents in the variable at baseline (z=-0. 30, p>0.05), suggesting that the groups did not exhibit a significant difference during the baseline stage. Table 4.2 contains further information.

Table 4.1 : Comparison of Height, Weight, and Training Background between Groups at Baseline

Variables	EG (n=30)	CG (n=30)	t-value	p-value
	Mean (SD)	Mean (SD)		
Height (Cm)	175.00 (1.26)	175.10(1.30)	-0.30	0.76
Weight (Kg)	69.90 (1.16)	70.07 (1.41)	-0.50	0.62
Training background (Month)	61.47 (4.49)	60.80 (4.25)	0.59	0.56

Noted: SD: standard deviation; EG: experimental group; CG: control group.

Table 4.2 : Mean Comparison between Groups for Age Variable at Baseline

Variables	EG (n=30)	CG (n=30)	z-value	p-value
	Median (IQR)	Median (IQR)		
Age (Year)	18.50 (1.00)	19.00 (1.00)	-0.30	0.77

Noted: IQR: interquartile range; EG: experimental group; CG: control group.

4.4 Dietary Intake and Daily Physical Activity

Dietary intake and daily physical activity are critical factors that may influence the outcomes of physical fitness and jumping difficulty movements. To ensure these variables do not confound the results, independent sample t-tests were conducted to evaluate the homogeneity between the two groups at baseline. The results showed no significant difference in dietary intake ($t = 0.11$; $p = 0.92$) and daily physical activity ($t = 0.36$; $p = 0.72$) between the EG and CG. These results suggest that the two groups were homogeneous regarding dietary intake and daily physical activity at baseline.

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Table 4.3 contains further details.

Table 4.3 : Comparison of Dietary Intake and Daily Physical Activity between Groups at Baseline

Variables	EG (n=30)	CG (n=30)	t-value	p-value
	Mean (SD)	Mean (SD)		
Dietary intake (Kcal)	2975.70 (161.45)	2989.10 (128.56)	0.11	0.92
Daily physical activity (Score)	6.83 (0.38)	6.86 (0.35)	0.36	0.72

Noted: SD: standard deviation; EG: experimental group; CG: control group.

4.5 Covariate Analysis

To better understand the contribution of the HIFT intervention plan, further analyses were conducted to evaluate its percentage contribution to improvements in physical fitness and jumping difficulty movements. Covariates such as age, weight, training background, dietary intake, and daily physical activity were analysed to ensure that the intervention's effect was independent of these variables. To evaluate the potential influence of covariates (e.g., age, weight, training background, dietary intake, and daily physical activity) on dependent variables (e.g., physical fitness and jumping difficulty movements), Pearson correlation analysis was conducted using baseline data. These results suggest that none of the covariates such as weight, training background, dietary intake, and daily physical activity had a statistically significant correlation with the dependent variables at baseline ($p > 0.05$). Therefore, these covariates were not included in the subsequent main effects analysis. The results are summarized in Table 4.4 below:

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Table 4.4 : Pearson Correlations between Groups for Dependent Variables at Baseline

Covariate	Age (r/p)	Height (r/p)	Weight (r/p)	Training background (r/p)	Dietary intake (r/p)	Physical activity (r/p)
Strength	-0.01/ 0.98	-.07/ 0.58	-0.24/ 0.07	0.06/ 0.65	0.09/ 0.47	-0.03/ 0.84
Power	0.04/ 0.75	0.07/ 0.60	-0.23/ 0.08	-0.01/ 0.97	0.13/ 0.32	0.08/ 0.55
Endurance	0.05/ 0.70	0.05/ 0.73	-0.08/ 0.53	-0.05/ 0.69	0.10/ 0.44	0.21/ 0.12
Speed	-0.12/ 0.35	0.01/ 0.98	0.15/ 0.27	-0.01/ 1.00	-0.11/ 0.42	0.02/ 0.89
Flexibility	0.31/ 0.06	0.05/ 0.72	0.06/ 0.68	-0.19/ 0.14	-0.01/ 0.95	0.06/ 0.63
Flying Kick	0.07/ 0.62	0.03/ 0.80	-0.04/ 0.78	0.09/ 0.51	0.07/ 0.62	0.03/ 0.85
Whirlwind Kick	0.10/ 0.47	0.01/ 0.96	-0.12/ 0.35	0.18/ 0.18	-0.06/ 0.64	-0.08/ 0.54
OLSF	0.09/ 0.48	0.17/ 0.24	-0.07/ 0.61	0.15/ 0.24	0.01/ 0.94	0.09/ 0.49
Side Somersault	0.13/ 0.32	-0.01/ 0.95	0.08/ 0.57	0.08/ 0.53	0.19/ 0.14	-0.05/ 0.73

Noted: OLSF: Outward Leg Swing in Flight; r: Pearson Correlation Coefficient. p: Significance (2-tailed).

4.6 Comparing Dependent Variables between EG and CG at Baseline

Before data analysis, the homogeneity assumptions of physical fitness and jumping difficulty movement variables in the baseline tests between the two groups were evaluated. Independent t-tests were used to assess the homogeneity of the two groups in physical fitness (strength: push-ups, power: standing long jump, endurance: jumping rope, and flexibility: sit-and-reach) and jumping difficulty movements (Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault). The results showed no significant difference ($p>0.05$) between the two groups regarding physical fitness and jumping difficulty movements variables, indicating that the two groups were homogeneous at baseline. More information can be found in Table 4.5. On the other hand, the speed data did not fit the normal distribution. Thus,

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the Mann-Whitney U test was applied. The results also revealed no significant difference between the control and experimental respondents in the variable at baseline (z=-0.25, p>0.05), suggesting that the groups did not exhibit a significant difference during the baseline stage. Table 4.6 contains further information.

Table 4.5 : Mean Comparison between Groups for Strength, Power, Endurance, Flexibility, and Jumping Difficulty Movements at Baseline

Variables	EG (n=30)	CG (n=30)	t-value	p-value
	Mean (SD)	Mean (SD)		
Push-ups (reps)	43.06 (7.26)	42.67 (7.48)	0.21	0.83
Standing long jump (cm)	238.00 (15.01)	238.17 (18.31)	-0.04	0.97
Jumping rope (reps)	89.77 (6.33)	90.50 (5.72)	-0.47	0.64
Sit-and-reach (cm)	15.32 (1.95)	15.97 (1.77)	-1.35	0.18
Flying Kick (points)	75.20 (8.16)	78.13 (6.09)	-1.58	0.12
Whirlwind Kick (points)	75.53 (9.57)	75.33 (8.18)	0.09	0.93
Outward Leg Swing in Flight (points)	75.53 (7.27)	75.23 (6.68)	0.17	0.87
Side Somersault (points)	75.97 (7.57)	76.30 (6.64)	-0.18	0.86

Noted: SD: standard deviation; EG: experimental group; CG: control group.

Table 4.6 : Mean Comparison between Groups for Speed Variables at Baseline

Variables	EG (n=30)	CG (n=30)	z-value	p-value
	Median (IQR)	Median (IQR)		
Sprint 30 m (s)	4.90 (0.30)	4.90 (0.22)	-0.25	0.80

Noted: IQR: interquartile range; EG: experimental group; CG: control group.

4.7 Effects of High-Intensity Functional Training on Physical Fitness Variables

This section analyses the five hypotheses of the first objective (Ho1-Ho5). To evaluate the effectiveness of HIFT training on physical fitness variables, the ANOVA and GEE technique based on repeated measurements was applied to assess the impact of HIFT training on the physical fitness of college male Wushu routine athletes. The possibility of this hypothesis being supported was inferred.

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4.7.1 Strength

The first area of physical fitness is strength, and the impact of HIFT training interventions on strength is observed through push-ups. The ANOVA method evaluated significant differences between different time groups. Baselines showed no significant differences in demographic characteristics, physical fitness, and jumping difficulty between the HIFT group (EG) and the control training group (CG). Table 4.7 shows the two groups' descriptive statistical data of strength variables at different time points. The average push-up score of the EG group at the Baseline was M=43.06 (SD=7.26), which increased to M=51.73 (SD=5.61) after the experiment. Similarly, the average push-up performance of the CG group during the Baseline was M=42.67 (SD=7.48), which increased to M=47.77 (SD=5.99) after the experiment.

Table 4.7 : Descriptive Statistics (Mean, SD) of Strength between Groups Across the Time

Variable	Group	Baseline	Week 6	Week 12
		Mean (SD)	Mean (SD)	Mean (SD)
Push-ups (reps)	EG	43.06 (7.26)	44.60 (6.53)	51.73 (5.61)
	CG	42.67 (7.48)	43.73 (7.22)	47.77 (5.99)

Noted: SD: standard deviation; EG: experimental group; CG: control group.

The ANOVA results showed no significant difference in the results of push-ups between the two groups (f=1.06, p=0.31). However, the effect of time on push-up scores is statistically significant (f=271.87, p<0.001). The interaction between time and groups was statistically significant (f=19.10, p<0.001), indicating a significant difference in push-up scores between the two groups at different times (baseline, post-test 1, and post-test 2). More information can be found in Table 4.8.

Table 4.8 : Results of ANOVA on Strength Scores

Variable	Source	f-value	df	p-value
Push-ups(reps)	Group	1.06	1	0.31
	Time	271.87*	2	<0.001
	Group*Time	19.10*	2	<0.001

Noted: df: degree of freedom; *p<0.05 significance level.

The Post Hoc test (Bonferroni) was used to evaluate the strength differences between two groups of male Wushu routine athletes at three different time points. Table 4.9 shows the test results. There were significant differences between baseline and post-test 1, baseline and post-test 2, as well as post-test 1 and post-test 2 in the EG group push-ups. Meanwhile, the results of push-ups in the CG group showed significant differences between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2.

Table 4.9 : Pairwise Comparison of Mean Scores for Strength across the Time

Variable	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CL for Difference	
						Lower	Upper
Push-ups (reps)	Baseline	Week 6	-1.30*	0.21	<0.001	-1.82	-0.78
	Baseline	Week 12	-6.88*	0.40	<0.001	-7.86	-5.91
	Week 6	Week 12	-5.58*	0.31	<0.001	-6.34	-4.83

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Multivariate analysis revealed a significant main effect of time (Wilks' Lambda = 0.14, $F = 169.36$, $p < 0.001$, Partial Eta Squared = 0.86), indicating substantial differences in scores across the time points. The interaction effect between group and time was also significant (Wilks' Lambda = 0.69, $F = 12.61$, $p < 0.001$, Partial Eta Squared = 0.31), suggesting that the patterns of change over time differed significantly between the experimental and control groups.

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Table 4.10 : Multivariate Test for Strength between Groups at Three Times

Effect	Index	Value	F	p-value	Partial Eta Squared
Time	Wilks' Lambda	0.14	169.36*	<0.001	0.86
Time * Group	Wilks' Lambda	0.69	12.61*	<0.001	0.31

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Figure 4.1 shows the average strength score for the entire period, and there is no significant difference in push-up scores between the two groups during the baseline. In post-test 1, neither group experienced significant changes. However, in post-test 2, both groups showed increased push-up scores, with EG's average scores significantly higher than CG's.

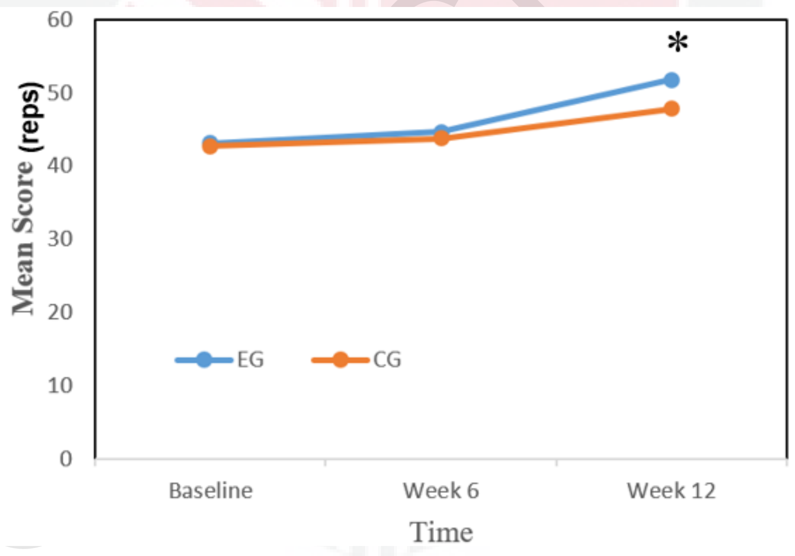

Figure 4.1 : The Mean Scores Changes of Strength across the Times between Groups

4.7.2 Power

The second area of physical fitness is power, observing the impact of HIFT training intervention on power through standing long jump results. Table 4.11 shows descriptive statistical data for two groups of power variables at different time points.

The average standing long jump score of the EG group in the baseline was M=238.00 (SD=15.01), which increased to M=249.73 (SD=10.61) in the post-test 2. Similarly, the CG group's average standing long jump score in the baseline was M=238.17 (SD=18.31), which increased to M=241.80 (SD=16.56) in post-test 2.

Table 4.11 : Descriptive Statistics (Mean, SD) of Power between Groups across the Time

Variable	Group	Baseline	Week 6	Week 12
		Mean (SD)	Mean (SD)	Mean (SD)
Standing long jump (cm)	EG	238.00 (15.01)	242.53 (12.37)	249.73 (10.61)
	CG	238.17 (18.31)	239.23 (17.77)	241.80 (16.56)

Noted: SD: standard deviation; EG: experimental group; CG: control group.

The ANOVA results showed no significant difference between the two groups for a long-standing jump (f=0.88, p=0.35). However, the effect of time on standing long jump scores is statistically significant (f=119.66, p<0.001). The interaction between time and groups was statistically significant (f=32.68, p<0.001), indicating a significant difference in standing long jump scores between the two groups at different times (baseline, post-test 1, and post-test 2). More information can be found in Table 4.12.

Table 4.12 : Results of ANOVA on Power Scores

Variable	Source	f-value	df	p-value
Standing long jump (cm)	Group	0.88	1	0.35
	Time	119.66*	2	<0.001
	Group*Time	32.68*	2	<0.001

Noted: df: degree of freedom; *p<0.05 significance level.

Evaluate the power differences between two groups of male Wushu routine athletes at three different time points using the Post Hoc test (Bonferroni) method. The experimental results are shown in Table 4.13. The EG standing long jump test showed significant differences between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2. At the same time, there were significant differences in the standing long jump scores of the CG group between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2.

Table 4.13 : Pairwise Comparison of Mean Scores for Power across the Time

Variable	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CL for Difference	
						Lower	Upper
Standing long jump (cm)	Baseline	Week 6	-2.80*	0.36	<0.001	-3.70	-1.90
	Baseline	Week 12	-7.68*	0.65	<0.001	-9.28	-6.09
	Week 6	Week 12	-4.88*	0.46	<0.001	-6.01	-3.76

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Multivariate analysis revealed a significant main effect of time (Wilks' Lambda = 0.29, F = 70.43, p < 0.001, Partial Eta Squared = 0.71), indicating substantial differences in scores across the time points. The interaction effect between group and time was also significant (Wilks' Lambda = 0.60, F = 19.35, p < 0.001, Partial Eta Squared = 0.40), suggesting that the patterns of change over time differed significantly between the experimental and control groups.

Table 4.14 : Multivariate Test for Power between Groups at Three Times

Effect	Index	Value	F	p-value	Partial Eta Squared
Time	Wilks' Lambda	0.29	70.43*	<0.001	0.71
Time * Group	Wilks' Lambda	0.60	19.35*	<0.001	0.40

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Figure 4.2 shows the average power scores for three different periods. In the baseline, the two groups had no significant difference in the standing long jump scores. In post-test 1, EG's average standing long jump score significantly increased, while CG did not change significantly. In post-test 2, both groups showed increased standing long jump scores, with EG's average standing long jump score significantly higher than CG's.

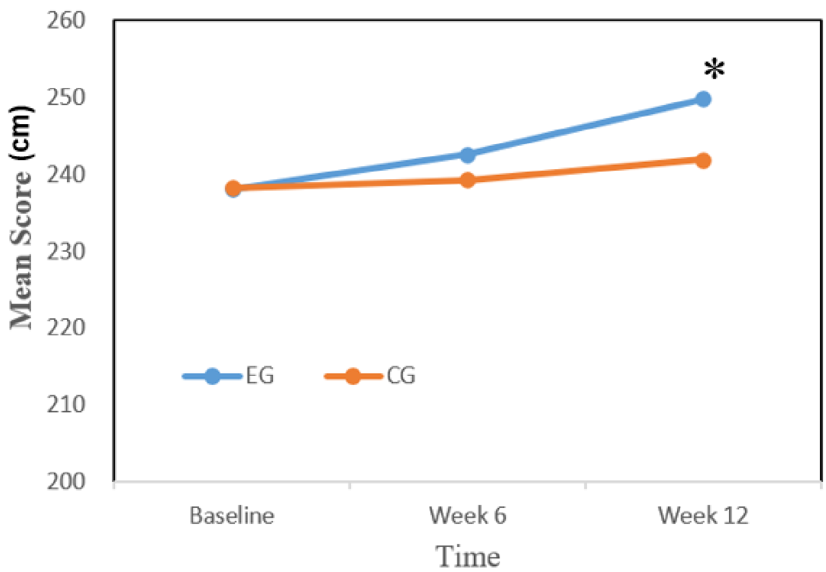

Figure 4.2 : The Mean Scores Changes of Power across the Times between Groups

4.7.3 Endurance

The third area of physical fitness is endurance, observing the impact of HIFT training intervention on endurance through jumping rope results. Table 4.15 shows the descriptive statistical data of endurance variables for the experimental and control groups at different time points. The average score of the EG group for jumping rope in the baseline was M=89.77 (SD=6.33), which increased to M=100.77 (SD=6.46) in the post-test 2. Similarly, the CG group's average score for jumping rope in the baseline was M=90.50 (SD=5.72), which increased to M=95.87 (SD=5.25) in post-test 2.

Table 4.15 : Descriptive Statistics (Mean, SD) of Endurance between Groups across the Time

Variable	Group	Baseline	Week 6	Week 12
		Mean (SD)	Mean (SD)	Mean (SD)
Jumping rope (reps)	EG	89.77 (6.33)	93.00 (6.25)	100.77 (6.46)
	CG	90.50 (5.72)	92.03(4.66)	95.87 (5.25)

Noted: SD: standard deviation; EG: experimental group; CG: control group.

The ANOVA results showed no significant difference in jumping rope performance between the two groups (f=1.41, p=0.24). However, the effect of time on jumping rope performance is statistically significant (f=265.85, p<0.001). The interaction between time and groups was statistically significant (f=31.33, p<0.001), indicating a significant difference in jumping rope scores between the two groups at different times (baseline, post-test 1, and post-test 2). More information can be found in Table 4.16.

Table 4.16 : Results of ANOVA on Endurance Scores

Variable	Source	f-value	df	p-value
Jumping rope (reps)	Group	1.41	1	0.24
	Time	265.85*	2	<0.001
	Group*Time	31.33*	2	<0.001

Noted: df: degree of freedom; *p<0.05 significance level.

The Post Hoc test (Bonferroni) method evaluated the endurance differences between two groups of male Wushu routine athletes at three different time points. The experimental results are shown in Table 4.17. The EG jump rope test shows significant differences between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2. At the same time, there were significant differences in the jump rope scores between the CG group baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2.

Table 4.17 : Pairwise Comparison of Mean Scores for Endurance across the Time

Variable	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CL for Difference	
						Lower	Upper
Jumping rope (reps)	Baseline	Week 6	-2.38*	0.28	<0.001	-3.07	-1.69
	Baseline	Week 12	-8.18*	0.46	<0.001	-9.31	-7.06
	Week 6	Week 12	-5.80*	0.34	<0.001	-6.63	-4.97

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Multivariate analysis revealed a significant main effect of time (Wilks' Lambda = 0.14, F = 170.23, p < 0.001, Partial Eta Squared = 0.86), indicating substantial differences in scores across the time points. The interaction effect between group and time was also significant (Wilks' Lambda = 0.59, F = 19.93, p < 0.001, Partial Eta Squared = 0.41), suggesting that the patterns of change over time differed significantly between the experimental and control groups.

Table 4.18 : Multivariate Test for Endurance between Groups at Three Times

Effect	Index	Value	F	p-value	Partial Eta Squared
Time	Wilks' Lambda	0.14	170.23*	<0.001	0.86
Time * Group	Wilks' Lambda	0.59	19.93*	<0.001	0.41

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Figure 4.3 shows the average endurance score for the entire period, and there was no significant difference in jump rope scores between the two groups during the baseline. In post-test 1, there was no significant change in the jump rope scores of both groups. However, in post-test 2, both groups showed increased jump rope scores, with EG's average jump rope score significantly higher than CG's.

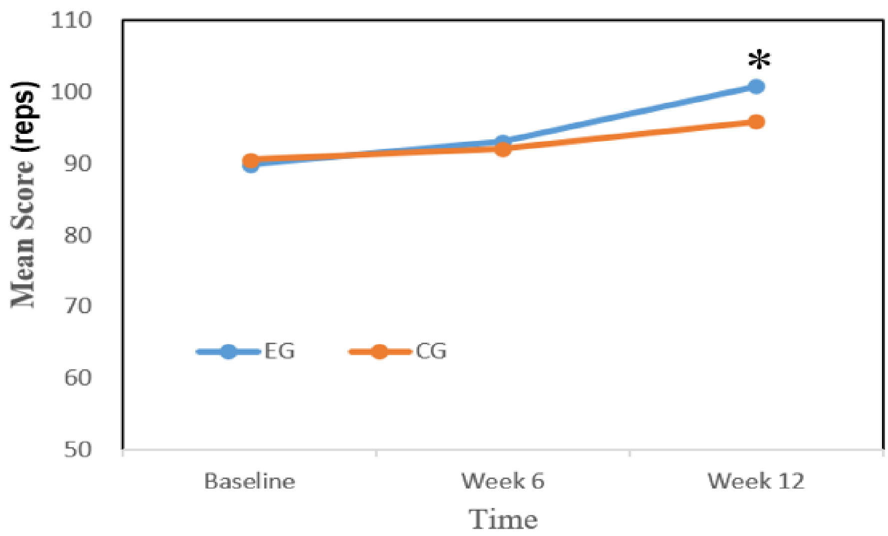

Figure 4.3 : The Mean Scores Changes of Endurance across the Times between Groups

4.7.4 Speed

The fourth area of physical fitness is speed, and the impact of HIFT training intervention on speed is observed through the results of a 30 m sprint. Table 4.19 shows the descriptive statistical data of the speed variable for EG and CG at different time points. In the baseline, the average score of the EG group in the 30 m sprint was M=4.86 (SD=0.15), which decreased to M=4.72 (SD=0.15) in the post-test 2. Similarly, the average score of the CG group's 30 m sprint in the baseline was M=4.87 (SD=0.15), which decreased to M=4.84 (SD=0.14) in post-test 2.

Table 4.19 : Descriptive Statistics (Mean, SD) of Speed between Groups across the Time

Variable	Group	Baseline	Week 6	Week 12
		Mean (SD)	Mean (SD)	Mean (SD)
Sprint 30 m (s)	EG	4.86 (0.15)	4.81 (0.13)	4.72 (0.15)
	CG	4.87 (0.15)	4.87 (0.15)	4.84 (0.14)

Noted: SD: standard deviation; EG: experimental group; CG: control group.

The GEE results showed no significant difference in the 30 m sprint performance between the two groups (x^2=2.88, p=0.090). However, the effect of time on the 30 m sprint was statistically significant (x^2=144.31, p<0.001). The interaction between time and groups was statistically significant (x^2=41.90, p<0.001), indicating significant differences in the 30 m sprint between the two groups at different times (baseline, post-test 1, and post-test 2). More information can be found in Table 4.20.

Table 4.20 : Results of GEE on Speed Scores

Variable	Source	Wald Chi-Square	df	p-value
Sprint 30 m (s)	Group	2.88	1	0.09
	Time	144.31*	2	<0.001
	Group*Time	41.90*	2	<0.001

Noted: df: degree of freedom; *p<0.05 significance level.

The Post Hoc test (Bonferroni) was used to evaluate the speed differences between two groups of male Wushu routine athletes at three different time points. The experimental results are shown in Table 4.21. The EG's 30 m sprint test showed significant differences between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2. At the same time, there was no significant difference in the 30 m sprint scores between the CG group baseline and post-test 1, while there was a significant difference between baseline and post-test 2 and between post-test 1 and post-test 2. In addition, HIFT training has a greater effect size on EG's 30 m sprint performance (d=0.93) than on CG (d=0.21)

Table 4.21 : Within Groups Comparison of Mean Scores for Speed across the Time

Variable	Group	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CL for Difference		Effect size (d)
							Lower	Upper	
Sprint 30 m (s)	EG	Baseline	Week 6	0.06*	0.05*	0.01	<0.001	0.03	0.93
		Baseline	Week 12	0.15*	0.14*	0.01	<0.001	0.11	
		Week 6	Week 12	0.10*	0.09*	0.01	<0.001	0.08	
	CG	Baseline	Week 6	0.02	0.01*	0.01	0.705	-0.02	0.21
		Baseline	Week 12	0.05*	0.03*	0.01	0.045	0.01	
		Week 6	Week 12	0.03*	0.03*	0.01	<0.001	0.01	

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

The Post Hoc test (Bonferroni) compares the performance of two groups of 30 m sprints at different times (baseline, post-test 1, post-test 2). The results of the 30 m sprint for both groups are shown in Table 4.22. The 30 m sprint of both groups showed no statistical significance in the baseline (p=0.86) and post-test 1 (p=0.11). However, in post-test 2, the difference in 30 m sprint scores between the two groups was statistically significant (p=0.001). By comparing the effects of EG and CG at different testing times, it was found that the effect size of 30 m sprint scores was relatively small in the baseline (d=0.07) and post-test 1 (d=0.43); However, in post-test 2 (d=0.83), the effect size was relatively large.

Table 4.22 : Comparison of Mean Scores for Speed between Groups at Three Times

Variable	Test	(I) Group	(J) Group	Mean Difference (I-J)	SE	p-value	95% CL for Difference		Effect size (d)
							Lower	Upper	
Sprint 30 m (s)	Baseline	EG	CG	-0.01	0.04	0.86	-0.08	0.07	0.07
	Week 6	EG	CG	-0.06	0.04	0.11	-0.13	0.01	0.43
	Week 12	EG	CG	-0.12*	0.04	0.001	-0.19	-0.05	0.83

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

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Figure 4.4 shows the average speed time for the entire experimental period. In the baseline, the two groups had no significant difference in the 30 m sprint. In post-test 1, EG's average 30 m sprint time significantly decreased, while CG did not change significantly. In post-test 2, there was a decrease in the 30 m sprint of both groups, and the average time of the 30 m sprint of EG was significantly shorter than that of CG.

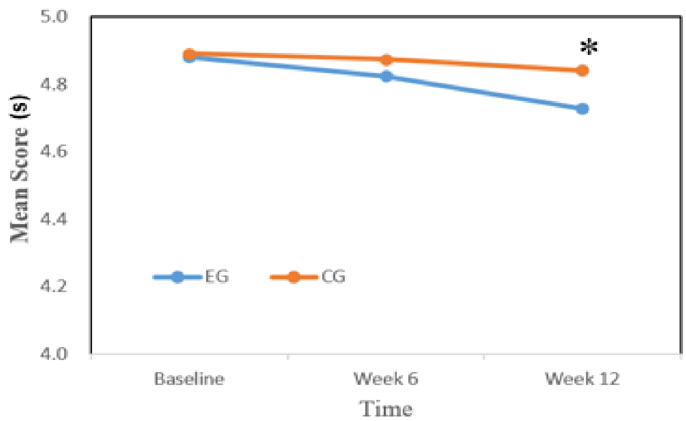

Figure 4.4 : The Mean Scores Changes of Speed across the Times between Groups

4.7.5 Flexibility

The fifth area of physical fitness is flexibility, and the impact of HIFT training intervention on flexibility is observed through sit-and-reach results. Table 4.23 shows the descriptive statistical data of flexibility variables for the experimental and control groups at different time points. In the baseline, the average score of the EG group in sit-and-reach was M=15.32 (SD=1.95), but in the post-test 2, it dropped to M=16.51 (SD=1.84). Similarly, the CG group had an average sit-and-reach score of M=15.97 (SD=1.77) in the baseline, which decreased to M=16.54 (SD=1.73) in the post-test 2.

Table 4.23 : Descriptive Statistics (Mean, SD) of Flexibility between Groups across the Time

Variable	Group	Baseline	Week 6	Week 12
		Mean (SD)	Mean (SD)	Mean (SD)
Sit-and-reach (cm)	EG	15.32 (1.95)	15.70 (1.80)	16.51 (1.84)
	CG	15.97 (1.77)	16.24 (1.71)	16.54 (1.73)

Noted: SD: standard deviation; EG: experimental group; CG: control group.

The ANOVA results showed no significant difference in sit-and-reach scores between the two groups (f=0.78, p=0.38). However, the effect of time on sit-and-reach is statistically significant (f=205.83, p<0.001). The interaction between time and groups was statistically significant (f=28.50, p<0.001), indicating significant differences in sit-and-reach between the two groups at different times (baseline, post-test 1, and post-test 2). More information can be found in Table 4.24.

Table 4.24 : Results of ANOVA on Flexibility Scores

Variable	Source	f-value	df	p-value
Sit-and-reach (cm)	Group	0.78	1	0.38
	Time	205.83*	2	<0.001
	Group*Time	28.50*	2	<0.001

Noted: df: degree of freedom; *p<0.05 significance level.

The Post Hoc test (Bonferroni) was used to evaluate the flexibility differences between two groups of male Wushu routine athletes at three different time points. Table 4.25 shows the test results. In the sit-and-reach test of EG, there were significant differences between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2. Meanwhile, there were significant differences in the sit-and-reach scores between the CG group's baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2.

Table 4.25 : Pairwise Comparison of Mean Scores for Flexibility across the Time

Variable	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CL for Difference	
						Lower	Upper
Sit-and-reach (cm)	Baseline	Week 6	-0.32*	0.04	<0.001	-0.41	-0.23
	Baseline	Week 12	-0.88*	0.05	<0.001	-1.01	-0.75
	Week 6	Week 12	-0.56*	0.04	<0.001	-0.66	-0.46

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Multivariate analysis revealed a significant main effect of time (Wilks' Lambda = 0.17, F = 134.98, p < 0.001, Partial Eta Squared = 0.83), indicating substantial differences in scores across the time points. The interaction effect between group and time was also significant (Wilks' Lambda = 0.58, F = 20.84, p < 0.001, Partial Eta Squared = 0.42), suggesting that the patterns of change over time differed significantly between the experimental and control groups.

Table 4.26 : Multivariate Test for Flexibility between Groups at Three Times

Effect	Index	Value	F	p-value	Partial Eta Squared
Time	Wilks' Lambda	0.17	134.98*	<0.001	0.83
Time * Group	Wilks' Lambda	0.58	20.84*	<0.001	0.42

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Figure 4.5 shows the average score of flexibility for three different periods. In the baseline, there was no significant difference in the average sit-and-reach scores between the two groups. In post-test 1, the average scores of sit-and-reaches in both EG and CG significantly increased. In post-test 2, the average scores of both groups in sit-and-reaches also significantly increased.

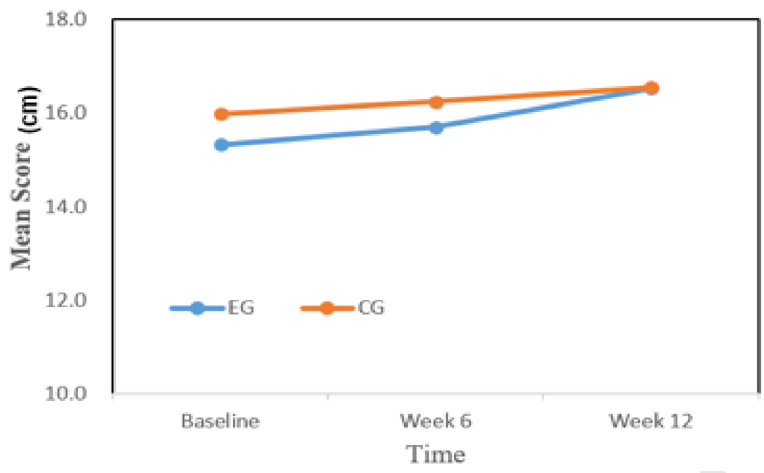

Figure 4.5 : The Mean Scores Changes of Flexibility across the Times between Groups

4.8 Effects of High-Intensity Functional Training on Jumping Difficulty Movements Variables

This section analyses four hypotheses for the second objective (Ho6-Ho9). To evaluate the effectiveness of HIFT training on the variable of jumping difficulty movements, the ANOVA method based on repeated measurements was used to evaluate the impact of HIFT training on the jumping difficulty of male Wushu routine athletes in college and to infer the possibility of supporting this hypothesis.

4.8.1 Flying Kick

The first area of jumping difficulty movements is the Flying Kick. The ANOVA method is used to evaluate whether there are significant differences between different time groups. Table 4.27 shows the descriptive statistical data of the Flying Kick scores of the experimental and control groups at different time points. The average Flying Kick score of the EG group during the baseline was M=75.20 (SD=8.16), which increased to M=82.77 (SD=6.95) during the post-test 2. Similarly, the average Flying Kick score of the CG group during the baseline period was M=78.13 (SD=6.09), which increased to M=81.87 (SD=4.84) during the post-test 2.

Table 4.27 : Descriptive Statistics (Mean, SD) of Flying Kick Scores between Groups across the Time

Variable	Group	Baseline	Week 6	Week 12
		Mean (SD)	Mean (SD)	Mean (SD)
Flying Kick (points)	EG	75.20 (8.16)	77.20 (7.75)	82.77 (6.95)
	CG	78.13 (6.09)	79.83 (5.43)	81.87 (4.84)

Noted: SD: standard deviation; EG: experimental group; CG: control group.

The ANOVA results showed no significant difference in the scores of the two Flying Kick (f=0.85, p=0.36). However, the effect of time on the Flying Kick scores is statistically significant (f=265.78, p<0.001). The interaction between time and groups is statistically significant (f=36.39, p<0.001), indicating significant differences in Flying Kick scores between the two groups at different times (baseline, post-test 1, and post-test 2). More information can be found in Table 4.28.

Table 4.28 : Results of ANOVA on Flying Kick Scores

Variable	Source	f-value	df	p-value
Flying Kick (points)	Group	0.85	1	0.36
	Time	265.78*	2	<0.001
	Group*Time	36.39*	2	<0.001

Noted: df: degree of freedom; *p<0.05 significance level.

Evaluate the difference in Flying Kick scores between two groups of male Wushu routine athletes at three different time points using the Post Hoc test (Bonferroni) method. The experimental results are shown in Table 4.29. In the Flying Kick of the EG group, there were significant differences between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2. Meanwhile, Flying Kick scores of the CG group showed significant differences between baseline and post-test 1, baseline and post-test

2, and post-test 1 and 2.

Table 4.29 : Pairwise Comparison of Mean Scores for Flying Kick across the Time

Variable	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CL for Difference	
						Lower	Upper
Flying Kick (points)	Baseline	Week 6	-1.85*	0.22	<0.001	-2.39	-1.31
	Baseline	Week 12	-5.65*	0.32	<0.001	-6.45	-4.85
	Week 6	Week 12	-3.80*	0.17	<0.001	-4.26	-3.34

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Multivariate analysis revealed a significant main effect of time (Wilks' Lambda = 0.12, F = 207.12, p < 0.001, Partial Eta Squared = 0.88), indicating substantial differences in scores across the time points. The interaction effect between group and time was also significant (Wilks' Lambda = 0.39, F = 45.30, p < 0.001, Partial Eta Squared = 0.61), suggesting that the patterns of change over time differed significantly between the experimental and control groups.

Table 4.30 : Multivariate Test for Flying Kick between Groups at Three Times

Effect	Index	Value	F	p-value	Partial Eta Squared
Time	Wilks' Lambda	0.12	207.12*	<0.001	0.88
Time * Group	Wilks' Lambda	0.39	45.30*	<0.001	0.61

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Figure 4.6 shows the average Flying Kick scores for the entire period. In the baseline, the two groups had no significant difference in Flying Kick scores. In post-test 1 and post-test 2, the Flying Kick scores of both groups increased, and the average Flying Kick score of EG was higher than that of CG.

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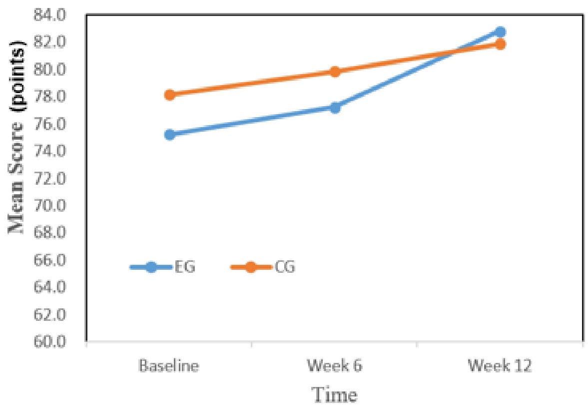

Figure 4.6 : The Mean Scores Changes of Flying Kick across the Times between Groups

4.8.2 Whirlwind Kick

The second area of jumping difficulty movements is the Whirlwind Kick. Table 4.31 presents descriptive statistical data on the Whirlwind Kick scores of the experimental and control groups at different time points. The average Whirlwind Kick score of the EG group in the baseline was M=75.53 (SD=9.57), which increased to M=82.70 (SD=7.16) in post-test 2. Similarly, the CG group had an average Whirlwind Kick score of M=75.33 (SD=8.18) in the baseline, which increased to M=78.77 (SD=7.59) in Post-Test 2.

Table 4.31 : Descriptive Statistics (Mean, SD) of Whirlwind Kick Scores between Groups across the Time

Variable	Group	Baseline	Week 6	Week 12
		Mean (SD)	Mean (SD)	Mean (SD)
Whirlwind Kick (points)	EG	75.53 (9.57)	77.47 (8.86)	82.70 (7.16)
	CG	75.33 (8.18)	76.70 (7.86)	78.77 (7.59)

Noted: SD: standard deviation; EG: experimental group; CG: control group.

The ANOVA results showed no significant difference in the scores of Whirlwind Kick between the two groups (f=0.60, p=0.44). However, the effect of time on Whirlwind

Kick scores is statistically significant (f=211.67, p<0.001). The interaction between time and groups is statistically significant (f=29.12, p<0.001), indicating significant differences in Whirlwind Kick scores between the two groups at different times (baseline, post-test 1, and post-test 2). More information can be found in Table 4.32.

Table 4.32 : Results of ANOVA on Whirlwind Kick Scores

Variable	Source	f-value	df	p-value
Whirlwind Kick (points)	Group	0.60	1	0.44
	Time	211.67*	2	<0.001
	Group*Time	29.12*	2	<0.001

Noted: df: degree of freedom; *p<0.05 significance level.

The Post Hoc test (Bonferroni) method evaluated the differences in Whirlwind Kick scores between two groups of male Wushu routine athletes at three different time points. The experimental results are shown in Table 4.33. In the Whirlwind Kick of the EG group, there were significant differences between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2. Meanwhile, the Whirlwind Kick scores of the CG group showed significant differences between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2.

Table 4.33 : Pairwise Comparison of Mean Scores for Whirlwind Kick across the Time

Variable	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CL for Difference	
						Lower	Upper
Whirlwind Kick (points)	Baseline	Week 6	-1.65*	0.17	<0.001	-2.06	-1.24
	Baseline	Week 12	-5.30*	0.34	<0.001	-6.14	-4.46
	Week 6	Week 12	-3.65*	0.25	<0.001	-4.27	-3.03

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

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Multivariate analysis revealed a significant main effect of time (Wilks' Lambda = 0.19, F = 119.51, p < 0.001, Partial Eta Squared = 0.81), indicating substantial differences in scores across the time points. The interaction effect between group and time was also significant (Wilks' Lambda = 0.60, F = 19.21, p < 0.001, Partial Eta Squared = 0.40), suggesting that the patterns of change over time differed significantly between the experimental and control groups.

Table 4.34 : Multivariate Test for Whirlwind Kick between Groups at Three Times

Effect	Index	Value	F	p-value	Partial Eta Squared
Time	Wilks' Lambda	0.19	119.51*	<0.001	0.81
Time * Group	Wilks' Lambda	0.60	19.21*	<0.001	0.40

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Figure 4.7 shows the average score of Whirlwind Kick for three different periods. In the baseline, the two groups had no significant difference in Whirlwind Kick scores. In post-tests 1 and 2, both groups increased Whirlwind Kick scores. In post-test 2, the average Whirlwind Kick score of EG is significantly higher than that of CG.

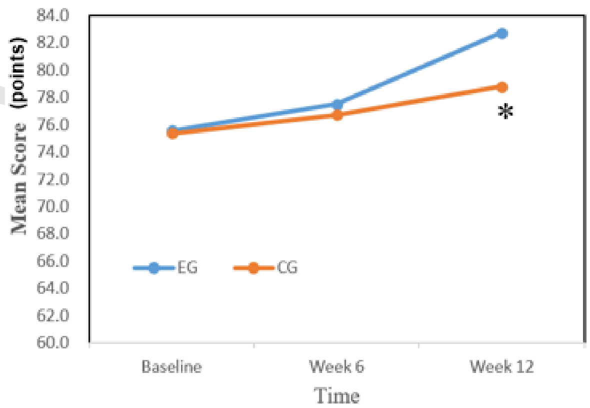

Figure 4.7 : The Mean Scores Changes of Whirlwind Kick across the Times between Groups

4.8.3 Outward Leg Swing in Flight

The Outward Leg Swing in Flight (OLSF) is the third area of jumping difficult movements. Table 4.35 presents descriptive statistical data on the OLSF scores of the experimental and control groups at different time points. The average OLSF score for the EG group in the baseline was M=75.53 (SD=7.27), which increased to M=80.83 (SD=6.08) in post-test 2. Similarly, the average OLSF score for the CG group in the baseline was M=75.23 (SD=6.68), which increased to M=78.57 (SD=5.89) in post-test 2.

Table 4.35 : Descriptive Statistics (Mean, SD) of Outward Leg Swing in Flight Scores between Groups across the Time

Variable	Group	Baseline	Week 6	Week 12
		Mean (SD)	Mean (SD)	Mean (SD)
OLSF (points)	EG	75.53 (7.27)	77.40 (6.75)	80.83 (6.08)
	CG	75.23 (6.68)	77.00 (6.45)	78.57 (5.89)

Noted: OLSF: Outward Leg Swing in Flight; SD: standard deviation; EG: experimental group; CG: control group.

The ANOVA results showed no significant difference in the OLSF scores between the two groups (f=0.35, p=0.56). However, the impact of time on the OLSF score is statistically significant (f=159.60, p<0.001). The interaction between time and groups is statistically significant (f=10.42, p<0.001), indicating a significant difference in the OLSF scores between the two groups at different times (baseline, post-test 1, and post-test 2). More information can be found in Table 4.36.

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Table 4.36 : Results of ANOVA on Outward Leg Swing in Flight Scores

Variable	Source	f-value	df	p-value
OLSF (points)	Group	0.35	1	0.56
	Time	159.60*	2	<0.001
	Group*Time	10.42*	2	<0.001

Noted: OLSF: Outward Leg Swing in Flight; df: degree of freedom; *p<0.05 significance level.

The Post Hoc test (Bonferroni) method evaluated the OLSF scores of two groups of male Wushu routine athletes at three different time points. The experimental results are shown in Table 4.37. In the OLSF of the EG group, there were significant differences between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2. Meanwhile, the OLSF scores of the CG group showed significant differences between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2.

Table 4.37 : Pairwise Comparison of Mean Scores for Outward Leg Swing in Flight across the Time

Variable	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CL for Difference	
						Lower	Upper
OLSF (points)	Baseline	Week 6	-1.817*	0.21	<0.001	-2.33	-1.30
	Baseline	Week 12	-4.317*	0.30	<0.001	-5.06	-3.57
	Week 6	Week 12	-2.500*	0.20	<0.001	-3.00	-1.20

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Multivariate analysis revealed a significant main effect of time (Wilks' Lambda = 0.22, F = 103.58, p < 0.001, Partial Eta Squared = 0.78), indicating substantial differences in scores across the time points. The interaction effect between group and time was also significant (Wilks' Lambda = 0.74, F = 10.30, p < 0.001, Partial Eta Squared = 0.27), suggesting that the patterns of change over time differed significantly between the experimental and control groups.

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Table 4.38 : Multivariate Test for Outward Leg Swing in Flight between Groups at Three Times

Effect	Index	Value	F	p-value	Partial Eta Squared
Time	Wilks' Lambda	0.22	103.58*	<0.001	0.78
Time * Group	Wilks' Lambda	0.74	10.30*	<0.001	0.27

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Figure 4.8 shows the average score of the OLSF over three different periods. There was no significant difference between the two groups in the Outward Leg Swing in Flight scores in the baseline. In post-tests 1 and 2, both groups' Outward Leg Swing in Flight scores increased. In post-test 2, The average score of EG's Outward Leg Swing in Flight is higher than that of CG.

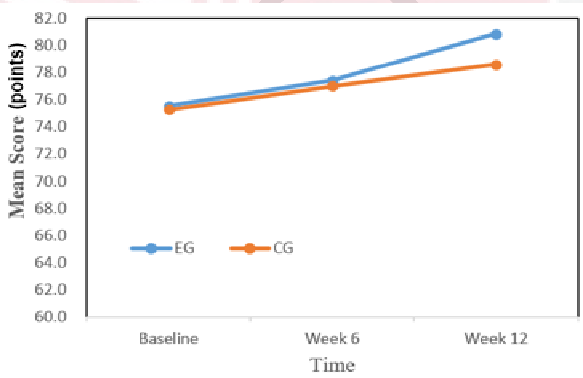

Figure 4.8 : The Mean Scores Changes of Outward Leg Swing in Flight across the Times between Groups

4.8.4 Side Somersault

The fourth area of jumping difficulty movements is Side Somersault. Table 4.39 presents descriptive statistical data on the Side Somersault scores of the experimental and control groups at different time points. The average score of Side Somersault for the EG group in the baseline was M=75.97 (SD=7.57), which increased to M=82.93 (SD=6.83) in the post-test 2. Similarly, the average score of Side Somersault in the

CG group in the baseline was M=76.30 (SD=6.64), which increased to M=80.00 (SD=5.59) in the post-test 2.

Table 4.39 : Descriptive Statistics (Mean, SD) of Side Somersault Scores between Groups across the Time

Variable	Group	Baseline	Week 6	Week 12
		Mean (SD)	Mean (SD)	Mean (SD)
Side Somersault (points)	EG	75.97 (7.57)	78.20 (7.31)	82.93 (6.83)
	CG	76.30 (6.64)	78.17 (5.81)	80.00 (5.59)

Noted: SD: standard deviation; EG: experimental group; CG: control group.

The ANOVA results showed no significant difference in Side Somersault scores between the two groups (f=0.27, p=0.61). However, the effect of time on the score of Side Somersault is statistically significant (f=237.57, p<0.001). The interaction between time and groups is statistically significant (f=26.28, p<0.001), indicating significant differences in Side Somersault scores between the two groups at different times (baseline, post-test 1, and post-test 2). More information can be found in Table 4.40.

Table 4.40 : Results of ANOVA on Side Somersault Scores

Variable	Source	f-value	df	p-value
Side Somersault (points)	Group	0.27	1	0.61
	Time	237.57*	2	<0.001
	Group*Time	26.28*	2	<0.001

Noted: df: degree of freedom; *p<0.05 significance level.

The Post Hoc test (Bonferroni) method evaluated the Side Somersault scores of two groups of male Wushu routine athletes at three different time points. The experimental results are shown in Table 4.41. In the Side Somersault of the EG group, there were significant differences between baseline and post-test 1, baseline and post-test 2, and

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post-test 1 and 2. Meanwhile, the score of Side Somersault in the CG group showed significant differences between baseline and post-test 1, baseline and post-test 2, and post-test 1 and 2.

Table 4.41 : Pairwise Comparison of Mean Scores for Side Somersault across the Time

Variable	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CL for Difference	
						Lower	Upper
Side Somersault (points)	Baseline	Week 6	-2.05*	0.22	<0.001	-2.58	-1.52
	Baseline	Week 12	-5.33*	0.31	<0.001	-6.09	-4.58
	Week 6	Week 12	-3.28*	0.21	<0.001	-3.79	-2.78

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Multivariate analysis revealed a significant main effect of time (Wilks' Lambda = 0.15, F = 160.89, $p < 0.001$, Partial Eta Squared = 0.85), indicating substantial differences in scores across the time points. The interaction effect between group and time was also significant (Wilks' Lambda = 0.54, F = 24.38, $p < 0.001$, Partial Eta Squared = 0.46), suggesting that the patterns of change over time differed significantly between the experimental and control groups.

Table 4.42 : Multivariate Test for Side Somersault between Groups at Three Times

Effect	Index	Value	F	p-value	Partial Eta Squared
Time	Wilks' Lambda	0.15	160.89*	<0.001	0.85
Time * Group	Wilks' Lambda	0.54	24.38*	<0.001	0.46

Noted: EG: experimental group; CG: control group; *p<0.05 significance level.

Figure 4.9 shows the average scores of Side Somersault for three different periods. In the baseline, there was no significant difference in the scores of Side Somersault between the two groups. In post-test 1 and post-test 2, the scores of Side Somersault in both groups increased. In post-test 2, the average score of EG on Side Somersault is higher than CG.

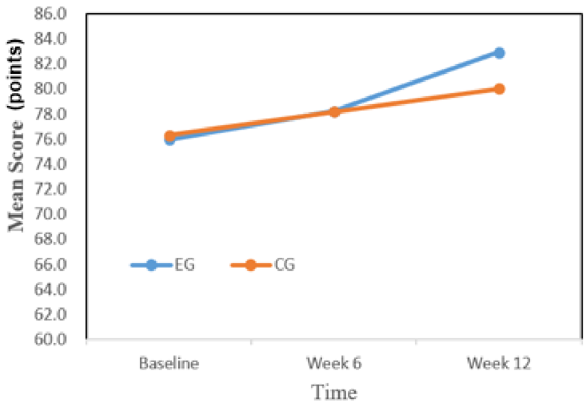

Figure 4.9 : The Mean Scores Changes of Side Somersault across the Times between Groups

4.9 Percentage Contribution of Intervention Plan

To calculate the percentage contribution of the HIFT intervention plan, eta-squared (η^2) values from the ANOVA results were used. These values indicate the proportion of total variance in dependent variables explained by the intervention. By controlling for covariates and analysing percentage contributions, this study provides a clearer understanding of the direct impact of HIFT training. The findings indicate that HIFT training significantly contributes to improvements in all measured variables, particularly in jumping difficulty movements such as Flying Kick (61%) and Side Somersault (46%). These results emphasize the value of HIFT in enhancing both general physical fitness and sport-specific performance for Wushu athletes. Table 4.43 summarizes the contribution percentages:

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Table 4.43 : Summarises the Contribution Percentages

Variables	Effect Source	η^2 Value	Contribution (%)
Strength (Push-ups)	Time * Group	0.31	31%
Power (Standing Long Jump)	Time * Group	0.40	40%
Endurance (Jumping Rope)	Time * Group	0.41	41%
Speed (30m Sprint)	Time * Group	0.46	46%
Flexibility (Sit-and-Reach)	Time * Group	0.42	42%
Flying Kick	Time * Group	0.61	61%
Whirlwind Kick	Time * Group	0.40	40%
Outward Leg Swing in Flight	Time * Group	0.27	27%
Side Somersault	Time * Group	0.46	46%

4.10 Conclusion

The results demonstrated that high-intensity functional training (HIFT) led to statistically significant improvements in multiple components of physical fitness and jumping difficulty movements among the participants. Specifically, the following components of physical fitness were significantly enhanced:

(1) **Strength**: Measured by push-up performance, HIFT contributed to a 31% improvement, indicating enhanced muscular endurance and upper-body strength.

(2) **Power**: Standing long jump results showed a 40% improvement, reflecting increased explosive power.

(3) **Endurance**: Jump rope performance improved by 41%, highlighting better cardiovascular and muscular endurance.

(4) **Speed**: 30m sprint times improved by 46%, indicating greater acceleration and quickness.

(5) **Flexibility**: Sit-and-reach tests revealed a 42% improvement, demonstrating enhanced flexibility and range of motion.

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In addition to physical fitness, HIFT had a substantial impact on jumping difficulty movements:

(1) **Flying Kick**: Improved by 61%, showing significant gains in coordination, power, and technique.

(2) **Whirlwind Kick**: Showed a 40% improvement, reflecting better balance, agility, and explosive strength.

(3) **Outward Leg Swing in Flight (OLSF)**: Improved by 27%, indicating moderate gains in flexibility and aerial control.

(4) **Side Somersault**: Improved by 46%, demonstrating enhanced overall athleticism and aerial performance.

While both groups experienced improvements over time, the significant interaction effects between time and group suggest that HIFT training had a uniquely beneficial impact compared to standard training methods. The absence of significant main effects for the group variable indicates that improvements were primarily driven by the intervention over time, rather than pre-existing differences between groups.

These findings reinforce the effectiveness of HIFT in enhancing both general physical fitness and specific Wushu jumping techniques. HIFT provides a comprehensive training approach that targets multiple aspects of athletic performance, making it a valuable method for Wushu routine athletes seeking to improve their competitive skills. This aligns with previous research highlighting the benefits of HIFT in improving physical performance in combat sports (Annmarie Chizewski et al., 2021; Banaszek et al., 2019; Cadegiani et al., 2019).

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In conclusion, HIFT training is a powerful tool for improving strength, power, endurance, speed, flexibility, and complex jumping techniques in Wushu athletes, offering a superior alternative to standard training programs.

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CHAPTER 5

DISCUSSION, CONCLUSION, IMPLICATION, AND RECOMMENDATION FOR FUTURE STUDY

5.1 Introduction

This chapter discusses the research findings and compares and analyses them with previous research findings. It explains the theories behind the research findings and how to use these theoretical explanations to improve athletic performance. In addition, this chapter discusses the implications of the research and offers suggestions for future research.

5.2 Discussion on Physical Fitness Variables

The following discussion focuses on why HIFT improves physical fitness: strength, power, endurance, speed, and flexibility.

5.2.1 Discussion on Strength

This section examines the effects of High-Intensity Functional Training (HIFT) and standard training methods on the strength performance of male Wushu routine athletes, as measured through the push-up test. The findings reveal a significant improvement in the strength performance of the experimental group (HIFT) compared to the control group (standard training), particularly after 12 weeks of intervention. This outcome highlights the differential impacts of the two training methods.

Strength Improvements in the Experimental Group

HIFT significantly enhanced the strength performance of the experimental group, as evidenced by the increased push-up scores over time. This improvement aligns with previous studies suggesting that HIFT's combination of high-intensity and multi-joint functional movements effectively stimulates muscular hypertrophy and neural adaptation (Feito et al., 2018). HIFT emphasises progressive overload through dynamic, compound exercises (e.g., push-ups, burpees, and weighted movements), which target multiple muscle groups simultaneously. These movements promote increased recruitment of fast-twitch muscle fibres, leading to greater strength gains (Bahremand et al., 2023).

Additionally, HIFT incorporates minimal rest intervals between exercises, creating a metabolic stress environment that further contributes to muscle growth and endurance. The continuous high-intensity demand may have triggered physiological adaptations such as improved motor unit activation and synchronization, thereby enhancing the athletes' ability to perform repetitive strength-based tasks like push-ups (Glassman, 2010).

Strength Improvements in the Control Group

In contrast, the control group, which followed a standard training program, exhibited only marginal improvements in strength performance. Standard Wushu training often focuses on isolated strength exercises (e.g., static holds, resistance band training) and repetitive low-intensity movements. While these methods are effective for building foundational strength and maintaining muscle endurance, they lack the dynamic intensity and multi-joint focus of HIFT (Yang & Guo, 2016). One potential limitation of standard training is its limited stimulation of fast-twitch muscle fibres, which are crucial for explosive strength development. Static and repetitive movements may predominantly engage slow-twitch muscle fibres, leading to slower strength gains compared to HIFT. Furthermore, the absence of progressive overload and varied exercise modalities in standard training may have contributed to the plateau observed in the control group's push-up performance (Yildiz et al., 2020).

The marginal improvement in the control group's strength performance can also be explained by the inherent limitations of their training protocol. The reliance on standard, repetitive movements with limited intensity likely contributed to the lack of significant neuromuscular adaptations. Studies by Wassenaar et al. (2021) and Cai et al. (2020) similarly noted that standard training methods, while effective for maintaining baseline strength, often fail to produce substantial gains in advanced athletes without additional intensity or variability. Moreover, the absence of structured progressive overload in the control group may have limited their strength development. Progressive overload is a key principle in strength training that systematically increases the training stimulus to drive continuous adaptation (Schoenfeld, 2010). Without this component, the control group's training may have plateaued early, leading to limited improvements.

Comparison between Experimental Group and Control Group

The interaction effect of time and group ($p < 0.001$) underscores the superior effectiveness of HIFT in enhancing strength over the 12-week intervention. The mechanisms underlying this difference can be attributed to:

(1) **Training Intensity and Progression**: HIFT's high-intensity approach progressively challenges the neuromuscular system, whereas standard

training maintains a steady-state intensity, which may not adequately stimulate strength development in advanced athletes (Bahrami et al., 2021).

(2) **Exercise Diversity**: The functional, multi-joint movements in HIFT provide varied stimuli, engaging multiple muscle groups and enhancing overall strength. Standard training often relies on single-plane or isolated movements, limiting its impact on holistic strength improvement (Heinrich et al., 2014).

(3) **Metabolic and Hormonal Responses**: HIFT induces higher metabolic and hormonal responses, such as increased levels of testosterone and growth hormone (Glassman, 2010), which are critical for muscle growth and strength development. Standard training's lower intensity may result in comparatively subdued physiological responses.

5.2.2 Discussion on Power

This section examines the effects of High-Intensity Functional Training (HIFT) and standard training methods on the power performance of male Wushu routine athletes, as measured through the standing long jump test. The results demonstrate significant improvements in the power performance of the experimental group (HIFT) compared to the control group (standard training), particularly after 12 weeks of intervention. This highlights the distinct advantages of HIFT in enhancing explosive lower-body power.

Power Improvements in the Experimental Group

The experimental group's standing long jump performance showed marked improvements over the course of the intervention. This aligns with previous research indicating that HIFT's dynamic, high-intensity exercises are highly effective in improving power through enhanced neuromuscular coordination and explosive force production (Feito et al., 2018; Heinrich et al., 2014). Key elements of the HIFT program, such as plyometric exercises (e.g., box jumps and power cleans) and weighted compound movements, directly target the muscles involved in jumping actions. These exercises enhance the stretch-shortening cycle, which is critical for producing explosive power. Furthermore, the inclusion of high-intensity intervals ensures sustained engagement of fast-twitch muscle fibres, leading to significant adaptations in both strength and power output (Bahremand et al., 2023). HIFT's emphasis on functional, multi-joint movements also promotes improved force transmission across the kinetic chain. This integrated approach likely contributed to the experimental group's superior ability to generate force during the standing long jump, as it reflects the cumulative effect of coordinated lower-body and core muscle engagement (Glassman, 2010).

Power Improvements in the Control Group

In contrast, the control group exhibited minimal improvements in power performance. Standard Wushu training often emphasises isolated strength exercises, static positions, and repetitive drills aimed at refining technique rather than developing explosive power (Cai et al., 2020). While these methods can enhance endurance and foundational strength, they are less effective in eliciting the rapid, high-intensity muscle contractions required for power development. The lack of dynamic and plyometric components in the control group's training regimen likely limited their ability to improve power performance. Static and repetitive exercises predominantly engage slow-twitch muscle fibres, which are not as responsive to the demands of explosive power tasks (Yang & Guo, 2016). Moreover, standard training methods may not provide sufficient overload or variability to stimulate significant neuromuscular adaptations (Wassenaar et al., 2021).

The minimal improvement in power performance observed in the control group is consistent with prior studies indicating that standard training methods lack the dynamic and high-intensity elements necessary for developing explosive power (Yildiz et al., 2020). While standard training emphasizes technical skill development, it does not sufficiently challenge the neuromuscular and metabolic systems required for power output. Additionally, the absence of progressive overload in the control group's regimen may have contributed to their limited power gains. Without systematic increases in training intensity or complexity, the athletes in the control group were unlikely to achieve the neuromuscular adaptations observed in the experimental group.

Comparison between Experimental Group and Control Group

The interaction effect of time and group ($p < 0.001$) underscores the superior effectiveness of HIFT in enhancing power over the 12-week intervention. The mechanisms underlying this difference can be attributed to:

(1) **Plyometric Training Integration**: HIFT's incorporation of plyometric exercises, such as box jumps and explosive lunges, directly improve the stretch-shortening cycle efficiency, enabling athletes to generate greater explosive force (Markovic & Mikulic, 2010). Standard training lacks this dynamic component, limiting power gains.

(2) **High-Intensity Loading**: The weighted, high-intensity movements in HIFT provide greater mechanical loading, leading to increased muscle fibre recruitment and hypertrophy of type II fibres (Schoenfeld, 2010). Standard training's reliance on lower-intensity, repetitive drills does not achieve the same level of stimulus.

(3) **Neural Adaptations**: HIFT promotes enhanced motor unit recruitment, synchronization, and firing rate, which are critical for explosive power development. Standard training's static and isolated nature offers a limited stimulus for these neural adaptations.

5.2.3 Discussion on Endurance

This study found that HIFT significantly enhanced the endurance performance of male Wushu routine athletes, as evidenced by marked improvements in their jumping rope performance. The experimental group outperformed the control group, particularly after 12 weeks of intervention. These findings align with prior studies (Romanova et al., 2023; Mischenko et al., 2021), which observed similar endurance gains in athletes using high-intensity training regimens.

Endurance Improvements in the Experimental Group (HIFT)

HIFT's impact on endurance can be attributed to its ability to enhance cardiovascular efficiency and aerobic capacity. The intermittent high-intensity nature of HIFT promotes increased cardiac output and mitochondrial density in skeletal muscles, which together improve oxygen transport and utilization efficiency. Additionally, HIFT reduces lactate accumulation through repeated short bursts of high-intensity activity, allowing athletes to sustain performance during prolonged high-intensity efforts (Heinrich et al., 2021). The experimental group benefited from exercises such as shuttle runs and short sprints, which improved cardiovascular fitness and muscular endurance. These dynamic training methods also supported faster lactate clearance, delaying fatigue onset and enabling participants to maintain high activity levels during prolonged routines. Importantly, the inclusion of multi-joint, functional movements contributed to improved endurance by training both the aerobic and anaerobic systems simultaneously.

Endurance Improvements in the Control Group

The control group also exhibited improvements in endurance performance, albeit to a lesser extent compared to the experimental group. Traditional Wushu training emphasizes repetitive practice of forms and basic drills, which enhance foundational endurance through steady-state aerobic exercises (Cai et al., 2020). However, these methods lack the variability and intensity required to elicit significant cardiovascular and metabolic adaptations associated with HIFT. The repetitive nature of standard training primarily engages slow-twitch muscle fibres, which are suited for endurance activities but lack the adaptability required for high-intensity demands (Yang & Guo, 2016). Furthermore, standard training does not integrate systematic interval training or progressive overload, which are essential for improving lactate threshold and overall endurance capacity. Although the control group showed moderate improvements in endurance, these gains were limited by the lack of high-intensity and interval-based exercises. Traditional Wushu training focuses on refining technique and developing overall fitness, but it does not adequately address the demands of prolonged high-intensity performance. The absence of structured progression or variability in training likely restricted the control group's ability to achieve significant endurance adaptations (Wassenaar et al., 2021).

Comparison between Experimental Group and Control Group

The results indicate a significant interaction effect between time and group ($p < 0.001$), highlighting the superior effectiveness of HIFT in improving endurance. The following mechanisms explain these differences:

1. **Training Variability**: HIFT incorporates a wide range of dynamic exercises, such as short sprints and high-intensity circuits, which activate both aerobic and anaerobic systems. In contrast, the control group relied on steady-state exercises with limited intensity, leading to less pronounced endurance gains (Gavanda et al., 2022).

2. **Lactate Tolerance**: HIFT's short recovery periods train the body to clear lactate efficiently, delaying fatigue during high-intensity efforts. Standard training lacks this focus, which may explain the smaller improvements in endurance performance (Heinrich et al., 2014).

3. **Cardiovascular Efficiency**: HIFT enhances oxygen delivery and utilization by improving cardiac output and capillary density in muscles. Standard training, while effective for basic endurance, does not challenge the cardiovascular system to the same degree (Ambrozy et al., 2022).

5.2.4 Discussion on Speed

This section examines the effects of High-Intensity Functional Training (HIFT) and standard training methods on the speed performance of male Wushu routine athletes, as measured through the 30m sprint test. The results demonstrate that HIFT significantly improved speed performance in the experimental group compared to the control group, particularly after 12 weeks of intervention. These findings underscore the advantages of HIFT in enhancing explosive acceleration and sprint performance, which are critical for Wushu athletes.

Speed Improvements in the Experimental Group

The experimental group exhibited significant improvements in the 30m sprint test after undergoing the HIFT intervention. This aligns with existing literature highlighting that HIFT's high-intensity interval exercises effectively enhance neuromuscular responsiveness and fast-twitch muscle fibre recruitment (Feito et al., 2018; Lundstrom et al., 2017). HIFT incorporates dynamic, explosive exercises such as sprints, plyometrics, and agility drills, which directly target the physiological systems responsible for speed development. For instance, short-distance sprints and explosive jump training improve starting power, acceleration, and maximum velocity by engaging the stretch-shortening cycle and promoting rapid muscle contraction (Bahremand et al., 2023). Furthermore, the functional, multi-joint nature of HIFT exercises optimizes inter-muscular coordination, enhancing overall movement efficiency and allowing athletes to achieve higher sprint speeds (Romanova et al., 2023).

Speed Improvements in the Control Group

In contrast, the control group displayed limited improvement in speed performance. Traditional Wushu training primarily emphasizes repetitive technique refinement, static postures, and endurance-based exercises, which lack the intensity and specificity required to develop explosive speed (Yang & Guo, 2016). While these methods contribute to foundational fitness and technical skill, they do not adequately stimulate the neuromuscular adaptations or muscle fibre recruitment necessary for sprinting performance (Cai et al., 2020). Additionally, standard training does not incorporate progressive overload or high-intensity intervals, which are essential for eliciting speed-specific improvements (Wassenaar et al., 2021). This limitation highlights the need for more dynamic and targeted exercises to supplement standard training approaches.

The control group's minimal improvement in speed performance aligns with prior research suggesting that standard training methods are less effective for developing speed-specific attributes (Yildiz et al., 2020). The absence of explosive drills and high-intensity intervals likely limited the neuromuscular and metabolic adaptations necessary for sprint improvement. Furthermore, standard training's lack of emphasis on acceleration and maximum velocity phases may have contributed to the limited progress observed. Without targeted exercises to enhance these critical sprinting components, athletes in the control group were unable to achieve substantial gains in speed.

Comparison between Experimental Group and Control Group

The interaction effect of time and group ($p < 0.001$) highlights the superior efficacy of HIFT in improving speed performance over the 12-week intervention. A detailed comparison reveals key differences:

(1) **Explosive Training**: HIFT emphasizes explosive movements, such as short sprints and plyometric drills, which directly improve acceleration and maximum velocity. Standard training lacks these components, limiting its ability to enhance sprint performance (Kapsis et al., 2022).

(2) **High-Intensity Intervals**: The incorporation of high-intensity intervals in HIFT enhances both anaerobic and aerobic capacities, enabling athletes to sustain higher speeds for longer durations. Standard training's reliance on steady-state or technique-focused exercises does not provide similar metabolic adaptations (Heinrich et al., 2014).

(3) **Neuromuscular Adaptations**: HIFT promotes rapid motor unit recruitment, synchronization, and firing rates, which are critical for explosive movements like sprints. In contrast, standard training methods do not provide sufficient stimuli to induce these neural adaptations.

(4) **Functional and Dynamic Movements**: The diverse, functional exercises in HIFT improve overall athleticism, including agility and reaction time, which are essential for speed. Standard training routines, being more static and repetitive, lack the variability required to optimize these attributes (Feito et al., 2018).

5.2.5 Discussion on Flexibility

This section examines the effects of High-Intensity Functional Training (HIFT) and standard training methods on the flexibility performance of male Wushu routine athletes, as measured through the sit-and-reach test. The results indicate that while the control group exhibited slightly better performance, the HIFT intervention also demonstrated potential long-term benefits for flexibility. This discussion delves into the observed differences, underlying mechanisms, and implications.

Flexibility Improvements in the Experimental Group

The experimental group's engagement in HIFT, which integrates dynamic stretching and functional exercises, aligns with evidence suggesting that dynamic stretching enhances muscle temperature, blood flow, and short-term joint mobility (Ferri-Caruana et al., 2020). HIFT's dynamic and high-intensity nature promotes neuromuscular responsiveness and overall physical preparedness, potentially contributing to functional flexibility improvements critical for Wushu performance (Feito et al., 2018). For instance, movements such as dynamic lunges and plyometric drills mimic sport-specific demands, enhancing movement fluency and instantaneous joint mobility. However, these improvements may not be fully captured by the static sit-and-reach test, which primarily measures lower back and hamstring extensibility.

Dynamic stretching, a cornerstone of HIFT, facilitates transient increases in range of motion through the activation of the stretch-shortening cycle. This mechanism enhances muscle elasticity and prepares athletes for explosive movements required in Wushu routines, such as high kicks and rapid directional changes. Although these benefits are integral to athletic performance, the limited impact on static flexibility metrics highlights the need for supplementary static stretching to optimize flexibility outcomes.

Flexibility Improvements in the Control Group

The control group, which followed traditional Wushu training emphasizing static stretching, demonstrated better performance in the sit-and-reach test. Static stretching induces long-term adaptations in muscle and connective tissue length, enhancing joint range of motion (Fukaya et al., 2021). Standard training's focus on prolonged static holds likely contributed to the observed improvements in static flexibility. For example, exercises such as seated forward bends and standing hamstring stretches directly target the muscle groups assessed by the sit-and-reach test, leading to more pronounced gains in this metric.

However, standard training's static and repetitive nature may limit its applicability to dynamic and functional flexibility demands in Wushu performance. The absence of high-intensity, movement-specific exercises restricts neuromuscular adaptations and the development of explosive flexibility required for complex routines (Yildiz et al., 2020).

Comparison between Experimental Group and Control Group

A detailed comparison reveals key distinctions in the mechanisms and outcomes of the two training approaches:

(1) **Dynamic vs. Static Stretching:** HIFT's reliance on dynamic stretching fosters short-term joint mobility and prepares athletes for explosive movements, whereas standard training's static stretching enhances long-term muscle and connective tissue extensibility (Ferri-Caruana et al., 2020; Fukaya et al., 2021).

(2) **Functional Movement Integration:** HIFT incorporates diverse, multi-joint exercises that simulate real-world movement patterns, improving overall athleticism and functional flexibility. Standard training lacks this variability, focusing instead on isolated static exercises (Feito et al., 2018).

(3) **Neuromuscular Adaptations:** HIFT promotes rapid motor unit recruitment and coordination, enhancing dynamic flexibility critical for Wushu performance. Standard training does not elicit comparable neuromuscular benefits, limiting its impact on sport-specific demands.

5.3 Discussion on Jumping Difficulty Movements Variables

The following discussion focuses on why HIFT improves the performance of jumping-difficulty movements such as Flying Kicks, Whirlwind Kicks, Outward Leg Swings in Flight, and in Side Somersaults.

5.3.1 Discussion on Flying Kick

This section examines the effects of High-Intensity Functional Training (HIFT) and standard training methods on the Flying Kick performance of male Wushu routine athletes. The results demonstrate that while HIFT improved the experimental group's Flying Kick performance, the difference compared to the control group was not statistically significant. These findings suggest the need to explore the specific mechanisms and training emphases of both methods to understand their relative effectiveness.

Improvements in the Experimental Group

The experimental group showed notable improvements in Flying Kick performance after the HIFT intervention. HIFT's emphasis on explosive, high-intensity movements, such as squats, jumps, and plyometric drills, directly enhances the physiological attributes critical for the Flying Kick, including lower limb strength, power, and neuromuscular coordination (Feito et al., 2018; Romanova et al., 2023). These exercises engage the stretch-shortening cycle, promoting rapid muscle contraction and improving take-off height and speed (Bahremand et al., 2023). Additionally, the dynamic and multi-joint nature of HIFT improves inter-muscular coordination, enabling athletes to execute complex aerial movements with greater efficiency. For instance, dynamic flexibility exercises in HIFT enhance joint mobility and muscle elasticity, which are crucial for achieving the range of motion required in Flying Kicks (Yildiz et al., 2020). Neuromuscular adaptations induced by HIFT, such as improved motor unit recruitment and firing rates, further support the execution of explosive movements like Flying Kicks.

Improvements in the Control Group

The control group, following traditional Wushu training, exhibited modest improvements in Flying Kick performance. Standard training's focus on technique refinement, static stretching, and endurance-based exercises develops foundational skills and flexibility but lacks the intensity and specificity necessary to optimize

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explosive power and coordination (Yang & Guo, 2016; Cai et al., 2020). While these methods contribute to muscle conditioning and technical consistency, they do not elicit the same neuromuscular or metabolic adaptations as HIFT. The limited gains observed in the control group align with prior research indicating that standard training is less effective in developing explosive attributes essential for complex movements like Flying Kicks (Wassenaar et al., 2021). The absence of progressive overload and high-intensity intervals in standard training likely restricted the athletes' ability to significantly enhance their take-off power and aerial control.

Comparison between Experimental Group and Control Group

Key differences in training emphasis and outcomes between the two groups highlight the unique advantages and limitations of each approach:

(1) **Explosive Training:** HIFT's incorporation of explosive drills, such as plyometrics and high-intensity jumps, directly enhances lower limb power and take-off height. Standard training lacks these elements, focusing instead on endurance and technique (Markovic & Mikulic, 2010).

(2) **Dynamic Flexibility:** HIFT emphasises dynamic stretching and functional movements, improving instantaneous flexibility and joint mobility required for aerial manoeuvres. Conversely, standard training's reliance on static stretching develops long-term flexibility but may not translate as effectively to dynamic performance (Ferri-Caruana et al., 2020).

(3) **Neuromuscular Adaptations:** HIFT promotes rapid motor unit synchronization and firing rates, essential for executing explosive movements. Standard training does not provide sufficient stimuli to induce these neural adaptations, limiting its impact on speed and power (Feito et al., 2018).

5.3.2 Discussion on Whirlwind Kick

This section evaluates the effects of High-Intensity Functional Training (HIFT) and traditional Wushu training on the performance of the Whirlwind Kick among male Wushu routine athletes. The findings indicate that while both groups demonstrated improvements, the HIFT group exhibited significantly greater gains in height, rotational speed, and execution quality after 12 weeks of intervention. These differences highlight the superior efficacy of HIFT in enhancing power, neuromuscular coordination, and endurance, all of which are critical for executing complex aerial manoeuvres such as the Whirlwind Kick.

Improvements in the Experimental Group

Athletes in the experimental group experienced substantial improvements in Whirlwind Kick execution, particularly in jump height, rotational velocity, and landing stability. This aligns with previous research highlighting the benefits of high-intensity, multi-joint exercises in improving explosive movements and neuromuscular adaptations (Feito et al., 2018; Heinrich et al., 2014). The key factors contributing to this improvement include: HIFT incorporates Olympic weightlifting movements (e.g., power cleans, snatches) and plyometric exercises (e.g., depth jumps, tuck jumps, and box jumps), which optimize the stretch-shortening cycle and improve rate of force development (Markovic & Mikulic, 2020). These exercises enhance fast-twitch muscle fibre recruitment, allowing for a more powerful and higher take-off, essential for executing the Whirlwind Kick with greater elevation (Cormie et al., 2021). The rotational component of the Whirlwind Kick requires exceptional core strength and angular velocity. HIFT training incorporates medicine ball rotational throws, anti-rotation exercises, and kettlebell swings, which improve oblique and transverse abdominis activation, leading to enhanced body control during rapid spins (Li et al., 2018). Increased trunk stability and coordination enable athletes to rotate faster while maintaining aerial control, reducing angular deceleration mid-flight (Gavanda et al., 2022).

Improvements in the Control Group

The control group exhibited moderate improvements in Whirlwind Kick performance, but these gains were primarily attributed to technical refinements rather than physiological adaptations. Traditional Wushu training emphasizes skill repetition, flexibility, and isometric strength, which provide certain benefits but lack the explosive and high-intensity stimuli necessary for substantial power development (Cai et al., 2020). The key limitations of the control group's training include: Standard training lacks progressive overload and plyometric-specific drills, resulting in slower gains in take-off power. Most exercises focus on static and dynamic flexibility, which improve range of motion but do not significantly enhance force production required for higher jumps (Yang & Guo, 2016). Although Wushu routines inherently involve rotational movements, standard training lacks dedicated rotational power exercises. Without targeted core rotation drills, athletes in the control group struggled to generate sufficient angular momentum, leading to slower and less controlled spins (Wassenaar et al., 2021).

Comparison between Experimental Group and Control Group

Key differences in training emphasis and outcomes between the two groups highlight the unique advantages and limitations of each approach:

(1) **Explosive Training:** HIFT group showed significant improvements due to high-intensity plyometrics and Olympic lifts. Standard training showed minimal improvements due to lack of explosive power focus (Wassenaar et al., 2021).

(2) **Rotational Speed:** HIFT group showed faster and more stable due to targeted core rotational training. Conversely, standard training group showed slower rotation due to lack of specialized rotational strength exercises (Ferri-Caruana et al., 2020).

5.3.3 Discussion on Outward Leg Swing in Flight

This section explores the effects of High-Intensity Functional Training (HIFT) on the performance of Outward Leg Swing in Flight (OLSF) among male Wushu routine athletes. The results indicate that while both the experimental group (EG) and the control group (CG) improved in OLSF performance, the improvements in the EG were more pronounced. This suggests that HIFT plays a critical role in enhancing specific physical and neuromuscular attributes required for executing OLSF, although the effect size was moderate compared to other jumping-difficulty movements.

Improvements in the Experimental Group

The experimental group showed significant improvements in OLSF performance following the HIFT intervention. The emphasis on explosive strength training, dynamic flexibility, and neuromuscular coordination contributed to this enhancement. HIFT exercises such as plyometric drills, squat jumps, and box jumps directly target the stretch-shortening cycle (SSC), which is essential for explosive leg movements like OLSF (Markovic & Mikulic, 2010). The SSC enhances muscle elasticity and enables rapid force production during the take-off phase, which is critical for achieving height and rotational control in OLSF.

Additionally, HIFT's focus on multi-joint, functional movements improve inter-muscular coordination, enabling athletes to generate the complex movement patterns required for OLSF with greater efficiency (Feito et al., 2018). Exercises that integrate core stability and lower limb power, such as medicine ball throws and kettlebell swings, help athletes maintain body control during aerial leg swings. The dynamic stretching component of HIFT further improves joint mobility and muscle elasticity, facilitating the wide range of motion necessary for OLSF (Yildiz et al., 2020).

Moreover, HIFT-induced neuromuscular adaptations—including enhanced motor unit recruitment, synchronization, and firing rates—contribute to better execution of OLSF. These adaptations enable athletes to initiate and control leg swings more explosively and with greater precision, leading to improved overall performance.

Improvements in the Control Group

The control group, following traditional Wushu training, also exhibited improvements in OLSF performance, albeit to a lesser extent. Standard training methods emphasize technical refinement, static stretching, and endurance-based exercises, which develop foundational skills necessary for Wushu but lack the intensity and specificity required to optimize explosive leg movements like OLSF (Yang & Guo, 2016).

Static stretching improved the flexibility of the CG athletes, contributing to better leg extension during the swing. However, static stretching has limited impact on dynamic performance compared to HIFT's dynamic flexibility exercises (Ferri-Caruana et al., 2020). Additionally, the traditional focus on endurance and repetitive technique practices improved muscle conditioning but did not significantly enhance the explosive power or neuromuscular coordination required for complex aerial

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manoeuvres.

The absence of progressive overload and explosive movement drills in standard training likely restricted the CG's ability to improve OLSF performance to the same extent as the EG. This aligns with previous studies suggesting that standard training methods are less effective in developing the power and coordination essential for complex Wushu movements (Wassenaar et al., 2021).

Comparison between Experimental Group and Control Group

A comparison between the experimental and control groups highlights the unique advantages of HIFT over standard training methods for improving OLSF performance.

(1) **Explosive Power Development**:
HIFT's inclusion of plyometric exercises and high-intensity jumps directly enhanced the athletes' lower limb power and take-off height, which are crucial for the outward swing phase. In contrast, standard training lacks these explosive elements, limiting the development of rapid force production necessary for OLSF (Cormie et al., 2011).

(2) **Dynamic Flexibility and Mobility**:
HIFT's focus on dynamic stretching and functional movements improved instantaneous flexibility and joint mobility, enabling athletes to achieve the full range of motion required for OLSF. Standard training's reliance on static stretching may develop long-term flexibility but does not translate as effectively to dynamic leg swings (Ferri-Caruana et al., 2020).

(3) **Core Stability and Balance**:
HIFT integrates core stability exercises that enhance postural control and balance during aerial movements. This allowed EG athletes to maintain better body alignment and control during the swing and landing phases of OLSF. Traditional Wushu training, while focusing on technique, does not emphasize

core strength to the same extent, limiting improvements in aerial balance (Behm et al., 2010).

5.3.4 Discussion on Side Somersault

This section analyses the effects of High-Intensity Functional Training (HIFT) on the performance of the Side Somersault among male Wushu routine athletes. The experimental group (EG) demonstrated significant improvements in side somersault performance following HIFT intervention compared to the control group (CG), which followed traditional Wushu training. These findings suggest that HIFT effectively enhances the explosive power, core stability, and neuromuscular coordination required for executing complex aerial manoeuvres like the side somersault.

Improvements in the Experimental Group

The EG's superior performance in the side somersault can be attributed to HIFT's focus on explosive strength, dynamic flexibility, and neuromuscular adaptations. The side somersault requires a rapid generation of force for vertical lift, precise rotational control, and a stable landing posture—all of which are enhanced through HIFT protocols. HIFT incorporates plyometric exercises such as depth jumps, box jumps, and medicine ball throws, which target the stretch-shortening cycle (SSC), crucial for explosive movements like the side somersault (Markovic & Mikulic, 2010). By engaging SSC mechanisms, athletes enhance their rate of force development (RFD), allowing for greater height and speed during take-off (Haff & Nimphius, 2012). The increased power output directly translates into higher and more controlled somersaults. The rotational aspect of the side somersault demands superior core strength and stability to maintain body alignment during the aerial phase. HIFT emphasizes functional core exercises such as planks with rotation, Russian twists, and kettlebell swings, which improve transverse abdominal and oblique muscle strength (Behm et al., 2010). Enhanced core stability allows athletes to control rotational velocity and axis, reducing deviations during the somersault and ensuring a clean landing. Flexibility is essential for achieving the optimal range of motion required in the somersault's take-off and landing phases. HIFT includes dynamic stretching and mobility drills that improve joint range of motion and muscle elasticity (Yildiz et al., 2020). This dynamic flexibility supports better leg extension during take-off and helps maintain proper form throughout the movement.

Improvements in the Control Group

The control group, which followed traditional Wushu training, also showed improvements in side somersault performance, albeit to a lesser degree. Standard training emphasizes technical drills, static stretching, and endurance-based exercises to refine movement patterns and flexibility (Yang & Guo, 2016). Repetitive practice of side somersault techniques helped the CG athletes develop muscle memory and improve movement consistency. This aligns with findings that technical drills are effective for improving motor control and movement precision (Wassenaar et al., 2021). The CG's reliance on static stretching contributed to long-term improvements in flexibility, which supports better form during the somersault. However, static stretching lacks the dynamic component necessary for explosive aerial performance and may even reduce muscle power output if not balanced with dynamic exercises (Ferri-Caruana et al., 2020). Traditional Wushu training's focus on endurance-based activities enhanced overall muscular conditioning, contributing to improved stamina during routines. However, endurance training does not target the explosive power and neuromuscular coordination required for optimal side somersault execution (Cai et al., 2020). Despite these improvements, the CG did not experience the same degree of neuromuscular adaptations or explosive strength gains as the EG, limiting their overall performance enhancement in side somersaults.

Comparison between Experimental and Control Groups

The comparative analysis between the EG and CG highlights the **distinct advantages** of HIFT over standard training methods in enhancing side somersault performance:

(1) **Explosive Power**:
HIFT's incorporation of high-intensity plyometrics significantly increased explosive strength and take-off power, while standard training's focus on endurance did not yield comparable results. Explosive movements are critical for achieving the height and speed necessary for side somersaults (Markovic & Mikulic, 2010).

(2) **Dynamic Core Engagement**:
HIFT's functional core exercises improved rotational stability and mid-air control, leading to more precise somersault execution. In contrast, the CG's training lacked the dynamic core engagement necessary for optimal aerial body control (Behm et al., 2010).

(3) **Flexibility and Mobility**:
While both groups improved in flexibility, HIFT’s emphasis on dynamic flexibility translated more effectively to aerial movement performance. Static stretching in standard training contributed to long-term flexibility but was less effective in improving dynamic range of motion required for explosive take-offs and controlled landings (Ferri-Caruana et al., 2020).

5.4 The Impact of HIFT on Physical Fitness and Jumping Difficulty Movements

HIFT plays a crucial role in improving the overall physical fitness and jumping difficulty movements of Wushu athletes. This study demonstrates that HIFT generates a synergistic effect among strength, power, endurance, speed, and flexibility, significantly enhancing athletic performance. The superiority of HIFT over standard training methods lies in its ability to simultaneously optimize multiple physical attributes while effectively integrating them within a high-intensity training environment.

Synergistic Effects of Physical Fitness Components

The observed improvements in strength, power, endurance, and speed collectively contributed to the enhancement of jumping difficulty movements. Strength and power serve as the foundation for explosive techniques such as the Flying Kick and Whirlwind Kick, where greater force production facilitates higher jumps and more controlled landings. HIFT enhances endurance through metabolic adaptations, enabling athletes to sustain peak performance throughout training cycles. Additionally, increased speed contributes to faster take-off and rotational movements, improving the execution quality of aerial techniques. Although flexibility did not show significant improvement through HIFT alone, it remains a key factor in optimizing the range of motion and reducing injury risk. Therefore, future training programs should integrate specialized flexibility regimens—such as dynamic stretching and proprioceptive neuromuscular facilitation (PNF) stretching—with HIFT to enhance joint mobility and muscle elasticity, ensuring athletes can fully leverage their strength and power during complex manoeuvres.

Optimization of Jumping Difficulty Movements through HIFT

Several key exercises within the HIFT framework played a decisive role in improving jumping ability:

(1) **Box Jumps and Depth Jumps**: Optimize the stretch-shortening cycle, enhancing power output required for difficult jumping manoeuvres.

(2) **High-Intensity Short-Interval Training**: Increases endurance and metabolic efficiency, allowing athletes to sustain high-performance levels over prolonged training sessions.

(3) **Olympic Weightlifting Exercises (e.g., Snatch, Clean and Jerk)**: Enhance neuromuscular coordination and explosiveness, directly impacting jump height and execution control.

(4) **Sprint Training**: Improves acceleration, enabling faster take-off in aerial movements.

(5) **Core Training**: Strengthens balance and control during dynamic jumps, ensuring greater stability and execution precision.

By systematically integrating these training elements, HIFT addresses potential shortcomings in traditional Wushu training methods when it comes to improving jumping difficulty movements.

Training Load Management and Adaptation

Another distinct advantage of HIFT lies in its adaptable load management strategies, allowing athletes to progressively adjust to higher training intensities while mitigating injury risks. Wushu training involves a high volume of repetitive, high-impact movements, and improper load management may lead to performance stagnation or increased susceptibility to injuries. Within the 12-week intervention of this study, training load adjustments were implemented through two primary aspects:

(1) **External Training Load (Training Volume and Intensity)**: Gradual progression in training intensity ensured an overload stimulus that facilitated physical development.

(2) **Internal Training Load (Physiological Stress Response)**: Heart rate monitoring was used to assess recovery status, preventing overtraining while optimizing adaptation.

5.5 Conclusion

Based on the current research objectives, the conclusions of this study are as follows:

(1) HIFT and standard training positively impact Chinese college male Wushu routine athletes' strength, power, endurance, speed, and flexibility. However, there was no significant difference in flexibility performance between HIFT and standard training during 12 weeks of training. In endurance and speed tests, HIFT training shows more essential advantages. In the sixth week of the experimental intervention, the two groups of athletes had no significant difference in strength, power, endurance, speed, and flexibility.

(2) HIFT and standard training positively impact the performance of Chinese college male Wushu routine athletes in Flying Kick, Whirlwind Kick, Outward Leg Swing in flight, and Side Somersault. However, except for the Whirlwind Kick, there was no significant difference between the two groups in the Flying Kick, Outward Leg Swing in Flight, and Side Somersault tests.

5.6 Implication

The significance of this study will be discussed in both theoretical and practical aspects.

5.6.1 Theoretical Implication

This study is based on the internal and external training load theory model by

Impellizzeri et al. (2019) and the HIFT training theory by Feito et al. (2018), focusing on exploring the application of these models in the impact of HIFT on the physical fitness and jumping difficulty movements of Chinese Wushu routine athletes. The research results show that HIFT significantly improves strength, power, endurance, speed, and Whirlwind Kick, which verifies the positive effect of external and internal training load theory on improving athlete physical fitness and jumping difficulty movements. Although there is no significant difference between HIFT and standard training in terms of flexibility, Flying Kick, Outward Leg Swing in Flight, and Side Somersault, the advantages of HIFT in endurance, speed, and Whirlwind Kick further support the effectiveness of HIFT. This discovery fills a gap in existing research. This study is the first to apply the HIFT training theory by Feito et al. (2018) to Wushu training, enriching the theoretical system of HIFT training and providing a new theoretical basis and empirical support for future related research.

5.6.2 Practical Implication

The results of this study indicate that HIFT has significant practical significance in improving the physical fitness and jumping difficulty of Wushu routine athletes. After 12 weeks of training, HIFT showed more significant advantages in endurance and speed tests, although there was no significant difference in flexibility performance compared to standard training. This indicates that coaches and athletes can use HIFT to enhance physical fitness, especially in training that requires high intensity and endurance. In addition, regarding jumping difficulty movements, HIFT positively impacts the performance of Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault. Although there is no significant difference in some movements compared to standardised training, the HIFT group has a higher average score after the experimental intervention. This discovery provides a new training method for Wushu coaches. This method has been registered in the clinical trial and will be able to be assessed by coaches who are interested in applying HIFT, especially for male Wushu players.

5.7 Recommendation for Future Study

Based on the research results, to further explore the impact of HIFT on Wushu routine athletes, the following future research suggestions are proposed:

(1) This study examined the effects of HIFT on the physical fitness and jumping difficulty movements of Chinese male college Wushu routine athletes. However, to fully understand the effects of HIFT, future studies should expand the range of subjects to include female athletes. This will help determine if HIFT has similar positive effects on female athletes, especially regarding physical fitness and jumping skills. Gender differences are significant in exercise physiology, and athletes of different genders may have substantial differences in physiological responses, training adaptations, and injury risk. Therefore, studying female athletes is necessary to optimise training protocols and enhance athletic performance.

(2) This study's analysis of physical fitness parameters only includes strength, power, endurance, speed, and flexibility. Future research should consider including more physical parameters such as body composition, agility, and balance to comprehensively evaluate the impact of HIFT. Changes in body composition can reveal the effects of HIFT on muscle mass and fat distribution. In contrast, agility and balance are crucial abilities in Wushu sports that directly affect athletes' performance and safety. By introducing these parameters, a more comprehensive understanding of the role of HIFT in physical training can be gained to optimise training protocols and improve the overall performance of athletes. In terms of jumping difficulty movements, this study omitted the analysis of spinning, flying straight leg kicks, and jumping difficulty linkage movements. Future research should

supplement these parameters to comprehensively evaluate the impact of HIFT on various jumping difficulty movements. These complex jumping movements have significant scoring weights in Wushu competitions and have high technical requirements and physical fitness demands. Analysing the effects of HIFT on these movements can lead to more effective training plans for athletes to enhance their technical level and competitive performance.

(3) This study observed significant physical and technical improvements during 12 weeks of HIFT training. However, to fully understand the long-term effects of HIFT, future studies should extend the duration of the intervention and observe the effects of HIFT on athletes' long-term performance, especially in terms of flexibility and other metrics that have yet to improve significantly. Extending the duration of the study could reveal the sustained effects of HIFT across training cycles and help determine the optimal training cycle and intensity. In addition, future research should combine HIFT with actual competition performance to evaluate the exact performance and effectiveness of training athletes in competitions. Actual competition conditions can provide real-world effects related to performance and ensure that training results are validated in a competition routine. This will reveal the direct effects of HIFT on competitive performance and help coaches and athletes develop more practical and effective training programmes. For example, training content and intensity can be more accurately adjusted by analysing competition performance data to enhance athletes' competitiveness. Combining the research with actual performance will provide coaches and athletes with more practical guidance to ensure that the training programme is effective in the experimental environment and improves athletic performance in the actual competition.

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APPENDICES

Appendix A

Request Permission

Permission 1: Request Permission from the Human Research Ethics Committee of Zhejiang Dongfang polytechnic, in China

浙江东方职业技术学院
ZHEJIANG DONGFANGPOLYTECHNIC

Institutional Review Board (IRB) Decision Letter

Approval No.: 1041668

Applicant:	ZHAO YUANYUAN School of Smart Health and Wellness at Health Medical College
IRB:	Zhejiang Dongfang Polytechnic, China
Title of project:	Effects of High Intensity Functional Training on Physical Fitness, Jumping Difficulty Movement among University Male Wushu Routine Athletes in China
Review category:	An original article
Decision:	Approval
Submission Date:	November 20th 2023

IRB Decision of Zhejiang Dongfang Polytechnic, China

November 24th 2023

Permission 2: Request Permission from Universiti Putra Malaysia's Human Research Ethics Committee

Ref. no: UPM/TNCPI/RMC/JKEUPM/1.4.18.2 (JKEUPM)
Date: 26 February 2024

Dear Prof./Dr./Mr./Ms.,

APPLICATION FOR JKEUPM ETHICAL CLEARANCE: APPROVED

With reference to the above, I am pleased to inform you that your application for ethical clearance for the research project entitled **'EFFECTS OF HIGH INTENSITY FUNCTIONAL TRAINING ON PHYSICAL FITNESS, JUMPING DIFFICULTY MOVEMENT AMONG UNIVERSITY MALE WUSHU ROUTINE ATHLETES IN CHINA'** has been approved.

The approval is **valid from 26 FEBRUARY 2024 until 26 FEBRUARY 2025.**

Please note that the official letter of approval will be issued as soon as possible. However, the ethical clearance is considered effective from the date of this email, and you may now proceed with your research.

Kindly remind the ethical approval is required in the case of amendments/ changes to the study documents/ study sites/ study team.

Researchers should also complete a Study Final Report upon study completion. The form can be obtained from the Ethics Committee for Research Involving Human Subjects (JKEUPM) website (http://www.tncpi.upm.edu.my/faildokumen).

If you have any enquiries, please contact at number 03-97691244/1602.

Note: Please use this reference number for any transaction:- **JKEUPM-2023-1359**

Thank you.

Yours faithfully,

Prof. Dr. Johnson Stanslas
Chair
Ethics Committee for Research Involving Human Subjects
Universiti Putra Malaysia

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Appendix B

Sample Size Calculation

Table 1 : Effect Size Calculation for Research Variables (Mean, SD)

Variable	Baseline Mean (SD)	Post-test Mean (SD)	Effect Size (f)	Reference
● Muscle Strength (push-ups)	11.03 (4.87)	12.23 (5.53)	0.23	Ambroży et al., 2022
● Power (Standing long jump)	201.2 (14.9)	204.83 (15.66)	0.24	Ambroży et al., 2022
● Endurance (Jump rope)	86 (6.73)	98 (7.51)	1.68	Mischenko et al., 2021
● Agility (Shuttle run 10 x 5 m)	19.37 (2.58)	18.71 (2.23)	0.27	Ambroży et al., 2022
● Speed (Running 200 m)	15.9 (0.43)	15.2 (0.28)	1.93	Mischenko et al., 2021
● Flexibility (Sit-and-reach)	10.33(4.67)	11.27 (4.75)	0.20	Ambroży et al., 2022
● Jumping difficulty movements	2.25 (0.45)	3.92 (0.67)	2.93	Sun, 2018

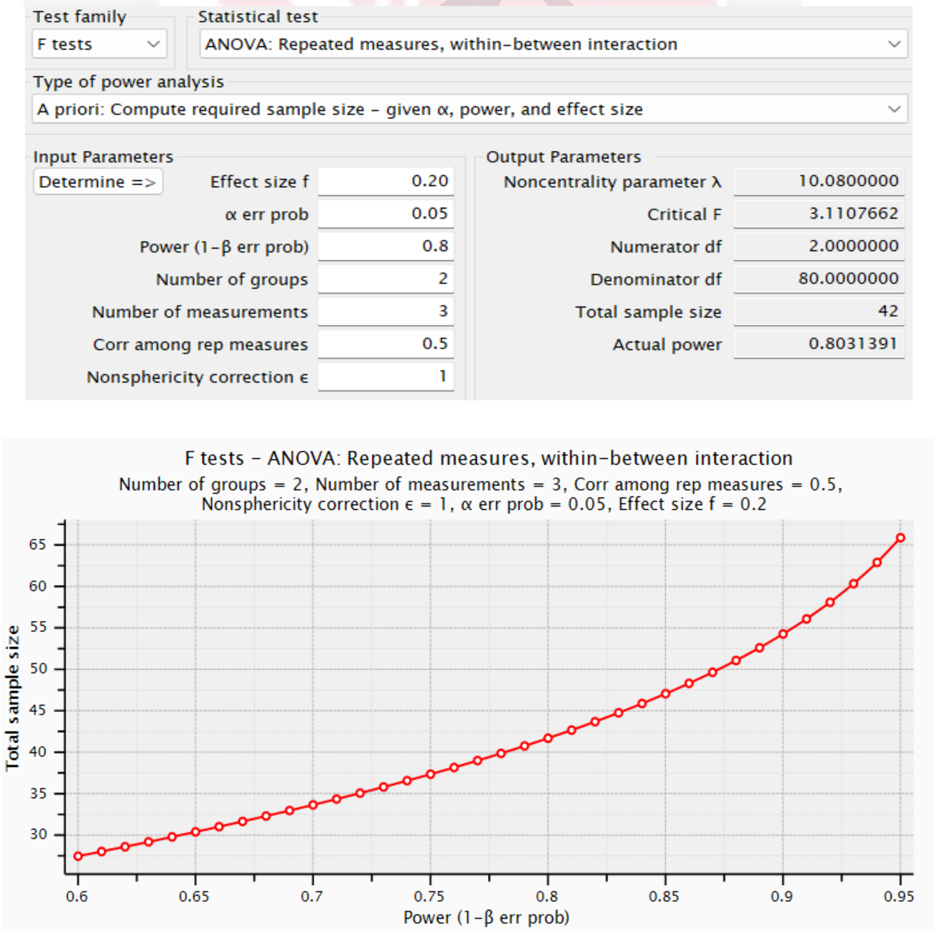

Figure 1 : Sample Size Calculation (G*Power)

Appendix C

Respondent's Information Sheet and Informed Consent Form

Please read the following information carefully and do not hesitate to discuss any questions you may have with the researcher.

1. STUDY TITLE:

Effects of High-intensity Functional Training on Physical Fitness, Jumping difficulty movements among University Male Wushu Routine Athletes in China

2. INTRODUCTION:

Wushu, known as the quintessence of China, has reached a relatively mature stage in its development process. However, there are still some problems in the current process of Wushu training. After 2001, the development of Wushu routines entered a bottleneck period, with relatively lagging behind in the innovation of training theories and technical movements. The challenging movements in Wushu routines involve multiple joints, upper and lower limb muscle groups, and core muscle groups. At present, many Wushu coaches lack professional knowledge in physical fitness training, and traditional methods continue to be used for physical fitness training in Wushu routines. Traditional Wushu routine physical fitness training often relies on single resistance weight training, emphasizing the size of resistance, number of repetitions, and number of sets. This single standard training mode often damages the sports chain during the training process, thereby reducing the performance of athletes. The continuous improvement of jumping difficulty in Wushu routine competition rules has been identified as a key factor affecting athletes' performance in Wushu routine competitions. The standardized methods of Wushu training can no longer meet the higher requirements of the new era and new rules. Many excellent Wushu routine athletes experience a decrease in movement quality due to insufficient physical fitness in the later stages of the competition, resulting in performance errors and affecting the competition results. Therefore, in physical fitness training, it is necessary to diversify training methods, adopt comprehensive training to stimulate various parts of the athlete's body, effectively combine physical fitness training with Wushu technical training, and enhance the scientific foundation of athlete training. The purpose of this study is to explore the impact of high-intensity functional training on the physical fitness and jumping difficulty of Wushu routine athletes.

This project includes three research stages: the first stage is literature research, exploring the impact of high-intensity functional training on athletes' physical fitness and skill performance. The second stage will determine the intervention protocol based on the analysis results of the first stage and start a 12-week intervention training; The third stage is resulting analysis, exploring whether high-intensity functional training will have a positive effect on the physical fitness and jumping difficulty performance of Wushu routine athletes. From literature review to result analysis, the project is expected to take 1.5 years. In the second stage, we plan to recruit 60 participants, including 30 participants in the experimental group and 30 participants in the control group.

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3. WHAT WILL YOU HAVE TO DO?

You voluntarily participate in 12 weeks high-intensive functional training program, which includes three tests (pretest, post test1, and post test2). The intervention frequency of the experiment is three times a week. The training time for each experiment is 1.5 hours, including 1 hour of physical training and half an hour of professional technical training. The physical training section includes multi joint functional movements such as push ups, kettlebell swings, box jumps, Romanian deadlifts, clean and jerk, and pull-ups.

In the course of this investigation, your adherence to the meticulously devised training protocol is imperative, precluding engagement in any alternative forms of physical exercise. In the two days antecedent to the examination, abstinence from alcoholic libations is enjoined, and on the day of testing, the consumption of beverages containing caffeine is likewise proscribed.

4. WHO SHOULD NOT PARTICIPATE IN THE STUDY?

The recruitment of participants was based on the inclusion and exclusion criteria of researchers.

The inclusion criteria for this study are as follows: 1) Male. 2) Aged 18-23 years old. 3) Health. 4) No experience of high-intensity functional training.

Moreover, the exclusion criteria of this study are as follows: 1) Athletes with physical surgery. 2) Have high-intensity functional training experience.

5. WHAT WILL BE THE BENEFITS OF THE STUDY:

(a) TO YOU AS THE SUBJECT?

Although individuals involved in this initiative do not receive immediate financial benefits, we aspire, through this research, to furnish valuable insights for the tailored formulation of training regimens for Wushu athletes. The athletes' physical fitness and performance in challenging jumping movements after the 12-week training will serve as benchmarks for their final evaluations. Additionally, athletes will have the opportunity to partake in the Wushu routine competition at the 15th National Games in 2025.

For the participants participating in this experiment, we may consider providing some financial support to thank you for your participation and time spent. Participants who have completed the entire intervention process and completed three tests will receive free gifts. The gift will be mailed directly to the participant's designated location. For more details, please contact and consult our researchers.

(b) TO THE INVESTIGATOR?

If the interventional experiment in this study yields positive outcomes, it can assist researchers in refining training protocols to meet the distinctive demands of Wushu routines. Armed with this knowledge, researchers can enhance the management of

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athletes' training loads, facilitating improved performance for Wushu athletes in their training endeavours. Furthermore, engagement in this research endeavour may contribute to bridging research gaps and accruing valuable experience for future research projects.

6. WHAT ARE THE POSSIBLE RISKS?

Participation in the study poses no detrimental or discomforting consequences, and it does not entail potential physical or psychological harm or distress. Respondents retain the autonomy to decide whether to engage in this research endeavour, with our assurance that your involvement will neither jeopardize nor impede any opportunities for government-provided services or assistance in the future.

7. WILL THE INFORMATION THAT YOU PROVIDE AND YOUR IDENTITY REMAIN CONFIDENTIAL?

We assure that any pertinent information concerning you will undergo anonymization in the publication of research findings and future papers. Your identity will remain undisclosed, with your name securely guarded to prevent any inadvertent disclosure. In the context of collaboration with third-party research entities and other individuals involved in the research, your data will be shared in an anonymized format, and neither the anonymized data nor your name will be compelled to be publicly disclosed. Interviewees retain the right to access their relevant information.

8. WHO SHOULD YOU CONTACT IF YOU HAVE ADDITIONAL QUESTIONS DURING THE COURSE OF THE RESEARCH?

Wang Xinzhi, Department of Sports Studies, Faculty of Educational Studies, Universiti Putra Malaysia， contact number: +86 15314222021, email: 1348326594@qq.com

Soh Kim Geok, Department of Sports Studies, Faculty of Educational Studies, Universiti Putra Malaysia， email: kims@upm.edu.my

If you have any questions about your rights as a participant in this study, please contact: The Secretariat, JKEUPM, at email address **jkeupm@upm.edu.my**

*Please initial here if you have read and understood the contents of this page*______

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9. CONSENT

I …………………………………… Identity Card No. …………………………… address…………………………………………………………………………… ……………………... ……………………………………………………. hereby voluntarily agree to take part in the research stated above *(clinical /drug trial/video recording/ focus group/interview-based/ questionnaire-based).

I have been informed about the nature of the research in terms of methodology, possible adverse
effects and complications (as written in the Respondent's Information Sheet). I understand that I have the right to withdraw from this research at any time without giving any reason whatsoever. I also understand that this study is confidential and all information provided with regard to my identity will remain private and confidential.

I* wish / do not wish to know the results related to my participation in the research

I agree/do not agree that the images/photos/video recordings/voice recordings related to me be used in any form of publication or presentation (if applicable)

* Delete where necessary

Signature……..…………………………. Signature ……..…………………………….
(Respondent) (Witness)

Date:……………………………….…….Name:………………………………….…..

I/C No. :………………………………….…..

I confirm that I have explained to the respondent the nature and purpose of the above-mentioned research.

Date ……..………………………… Signature ……..…………………………….
(Researcher)

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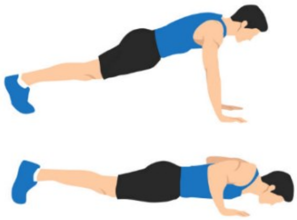
Appendix D

Table 1 : Training Intervention Information

Week	Frequency	Types	Duration (min)	Warm -up /min	Physical training /min	Cool-down /min	Intensity	Suggestions
1-2	3times/week	HIFT	60min	10min	40min	10	80% HRmax	
		Standard Training					(50%-60%) HRmax	
3-4	3times/week	HIFT	60min	10min	40min	10	80% HRmax	
		Standard Training					(50%-60%) HRmax	
5-6	3times/week	HIFT	60min	10min	40min	10	85% HRmax	
		Standard Training					(55%-65%) HRmax	
7-8	3times/week	HIFT	60min	10min	40min	10	85% HRmax	
		Standard Training					(55%-65%) HRmax	
9-10	3times/week	HIFT	60min	10min	40min	10	90% HRmax	
		Standard Training					(60%-70%) HRmax	
11-12	3times/week	HIFT	60min	10min	40min	10	90% HRmax	
		Standard Training					(60%-70%) HRmax	

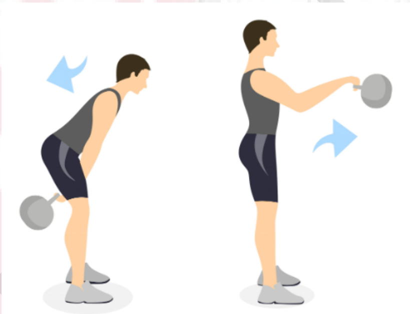
1 Movements in the Intervention

1.1 Push-Ups:



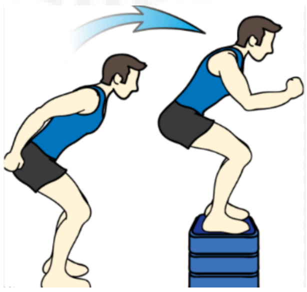
The participants lay face down on the floor with their hands under their shoulders. Keep the legs and body straight, and lower the elbow joint by bending it 90 degrees through continuous movement of the torso. Press down on the floor until the arms are fully extended (O. A. Yu, 2021).

1.2 Kettlebell Swing:



Participants spread their feet shoulder width apart, bend their knees, and grab the kettlebell with both hands. Start the swing by articulating the hip joint, arcing upwards to chest height, tightening the gluteus and abdominal muscles while keeping the arms extended, then let the kettlebell fall naturally until it reaches the bottom position, and then swing again between the legs for the next movement (Lake & Lauder, 2012).

1.3 Box Jumps:



Participants should start with their feet shoulder width apart, bend their ankles, knees, and hips, and jump forward and up with force. They should land on the box with their feet, then jump off with their feet shoulder width apart, with their knees slightly bent and landing on the ground (Schuda & Murphy, 2019).

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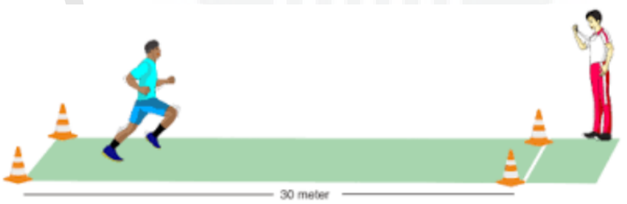
1.4 Cartwheels:

The participants start from a stride position, with their arms relaxed on both sides, then their hind legs flipped upwards, their hands in a straight line supporting the ground, their bodies moving on the side plane, and then landing one foot after another.

1.5 Romanian Deadlift:

Starting from the standing position, participants should spread their feet shoulder width apart, place the barbell in front of their thighs, straighten their back, and slowly lower the barbell closer to their thighs. The knees should be kept in a bent position of approximately 15 degrees until they are below the knee joint, and then when they rise, the hips and knees should be extended simultaneously until they return to the standing position (Bird & Barrington-Higgs, 2010).

1.6 30m Sprint:



Set cones at 0 and 30 meters along a straight line. Participants place their toes on the starting line or behind the starting line, start from a stationary position, and sprint at maximum speed over the cone at a distance of 30 meters before safely slowing down (Meyers et al., 2015).

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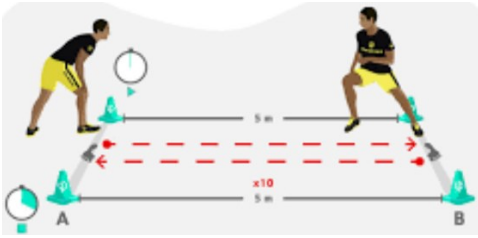
1.7 Shuttle Run 10 x 5 m:



Set up cones at 0 and 5 meters along a straight line, and participants run to the cone 5 meters away based on the signal, then return to the starting line. This process was repeated five times without interruption (covering a total of 50 meters). At each cone, both feet must fully cross the cone (Ambrozy et al., 2022).

1.8 Pull-Ups:

Participants use internal grip to grab the crossbar and hang their bodies; Then bend your arms, lift your body upwards, cross the crossbar with your chin, and return to the initial suspended state (Ambrozy et al., 2022).

1.9 Clean and jerk (30kg):

Participants spread their legs at shoulder width apart and used hook grip to grab the 30kg barbell in front of their legs. Once the barbell is above the knee, forcefully extend the hips, lift the barbell as high as possible, squat quickly, and place the barbell above the collarbone. Then bend the knees, keep the back vertical, squat slightly, and then explosively extend the knees, pushing the barbell up and off the shoulders, using the arms to push it up, lifting the barbell above the head, straightening the arms, and keeping all parts of the body in the same plane (Shalmanov & Lukunina, 2020).

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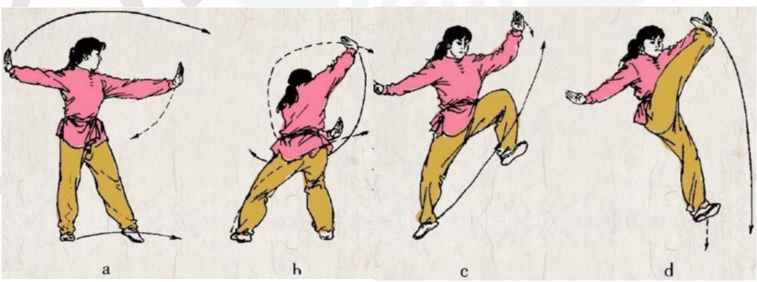
1.10 Straight-Leg Squat：

Participants stand on one leg, with their feet pointing straight ahead, and the knees of their other leg slightly bent, continuously squatting in a slow and controllable manner while maintaining balance (Crossley et al., 2011).

1.11 Jumping Rope：

Participants rotate the rope with their arms, while their legs bounce repeatedly, maintaining vertical take-off and landing until the exercise is over (Trecroci et al., 2015).

1.12 Jumping Whirlwind Kick：



Participants swing their legs straight, take off with their legs straight, spin 270 degrees into the air, tap the soles of their feet with their opposite hands, feet above their shoulders, tap loudly, and spin 360 degrees to land (Su, 2015).

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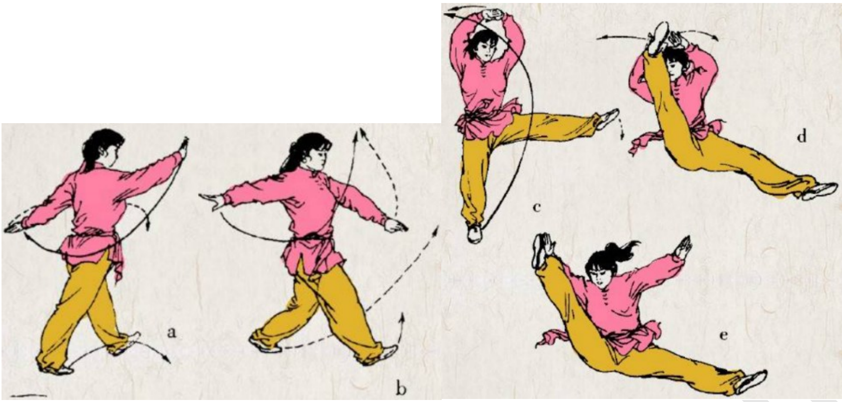
1.13 Jumping Outward Leg Swing in Flight:



Participants should swing their legs high, extend their take-off legs straight and swing them outward, with their feet flat and above their shoulders. They should tap their feet with both hands in sequence to form three sounds, with no one sound falling in the air (Su, 2015).

Table 2 : Intervention Protocol (1-2 weeks)

Experimental group	Intensity	Sets/reps	Rest (sets/reps)	Control group	Intensity	Sets/reps	Rest (sets/reps)	Suggestions
Warm up								
Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	
Physical training								
15 push-ups. 30s kettlebell swing 10 box jumps 5 cartwheels 5 Romanian deadlifts (70kg) 30m sprint	80% HRmax	3 rounds	90s/30s	Push-ups. Leap frog Knee bending vertical jump Back extension exercise Burpee Curl-up	50%-60% HRmax	3 sets / 10 reps	60s	
Cool down								
Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	

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Table 3 : Intervention Protocol (3-4 weeks)

Experimental group	Intensity	Sets/reps	Rest (sets/reps)	Control group	Intensity	Sets/reps	Rest (sets/reps)	Suggestions
Warm up								
Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	
Physical training								
15 push-ups. 30s kettlebell swing 10 box jumps 5 cartwheels 5 Romanian deadlifts (70kg) 30m sprint	80% HRmax	AMRAP (as many rounds as possible)	90s/30s	Push-ups. Leap frog Knee bending vertical jump Back extension exercise Burpee Curl-up	50%-60% HRmax	3 sets/10 reps	60s	
Cool down								
Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	

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Table 4 : Intervention Protocol (5-6 weeks)

Experimental group	Intensity	Sets/reps	Rest (sets/reps)	Control group	Intensity	Sets/reps	Rest (sets/reps)	Suggestions
Warm up								
Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	
Physical training								
Shuttle run 10 x 5 m 20 pull-ups 15 box jumps 5 clean and jerk(30kg) 10 Romanian deadlifts (75kg) 10 x 2 straight-leg squat	85% HRmax	AMRAP	90s/20s	Bench press (60%/1RM). Deadlifts (65%/1RM) Barbell Biceps Curl (50%/1RM) Barbell Squat (65%/1RM) Sitting position with knee extension (65%/1RM) Calf raise (50%/1RM)	55%-65% HRmax	3 sets/ 8-10 reps	60s	
Cool down								
Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	

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Table 5 : Intervention Protocol (7-8 weeks)

Experimental group	Intensity	Sets/reps	Rest (sets/reps)	Control group	Intensity	Sets/reps	Rest (sets/reps)	Suggestions
Warm up								
Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	
Physical training								
Shuttle run 10 x 5 m 20 pull-ups 15 box jumps 5 clean and jerk(30kg) 10 Romanian deadlifts (75kg) 10 x 2 straight-leg squat	85% HRmax	AMRAP	90s/20s	Bench press (60%/1RM). Deadlifts (65%/1RM) Barbell Biceps Curl (50%/1RM) Barbell Squat (65%/1RM) Sitting position with knee extension (65%/1RM) Calf raise (50%/1RM)	55%-65% HRmax	3 sets/ 8-10 reps	60s	
Cool down								
Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	

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Table 6 : Intervention Protocol (9-10 weeks)

Experimental group	Intensity	Sets/reps	Rest (sets/reps)	Control group	Intensity	Sets/reps	Rest (sets/reps)	Suggestions
Warm up								
Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	
Physical training								
30s jumping rope 10 clean and jerk 5 jumping Whirlwind Kick 10 Romanian deadlifts (75kg) 5 jumping Outward Leg Swing in Flight 10 x 2 single-leg squat	90% HRmax	AMRAP	90s/10s	Bench press (70%/1RM). Deadlifts (70%/1RM) Barbell Biceps Curl (60%/1RM) Barbell Squat (70%/1RM) Sitting position with weight-bearing knee extension (70%/1RM) Calf raise (60%/1RM)	60%-70% HRmax	3 sets/ 8-10 reps	60s	
Cool down								
Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	

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Table 7 : Intervention Protocol (11-12 weeks)

Experimental group	Intensity	Sets/reps	Rest (sets/reps)	Control group	Intensity	Sets/reps	Rest (sets/reps)	Suggestions
Warm up								
Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	Move the wrist, shoulder, hip, knee, and ankle.	< 60% HRmax	2sets / 4reps	< 10s	
Physical training								
30s jumping rope 10 clean and jerk 5 jumping Whirlwind Kick 10 Romanian deadlifts (75kg) 5 jumping Outward Leg Swing in Flight 10 x 2 single-leg squat	90% HRmax	AMRAP	90s/10s	Bench press (70%/1RM). Deadlifts (70%/1RM) Barbell Biceps Curl (60%/1RM) Barbell Squat (70%/1RM) Sitting position with weight-bearing knee extension (70%/1RM) Calf raise (60%/1RM)	60%-70% HRmax	3 sets/ 8-10 reps	60s	
Cool down								
Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	Muscle stretching (Upper trapezius stretch, lunge with spinal twist, cobra pose, side split, sit-and-reach)	< 60% HRmax	30 seconds each side	< 10s	

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Appendix E

Validation of Experts for Instrument Contents

Dear experts:

My name is Wang Xinzhi, thank you for providing valuable feedback and suggestions for this study amidst your busy schedule! I am a doctoral student in the Department of Sports at the Universiti Putra Malaysia, under the supervision of Professor Soh Kim Geok. I am completing my doctoral thesis "Effects of High- Intensity Functional Training on Physical Fitness, Jumping Difficulty Movement among University Male Wushu Routine Athletes in China.". You have a wealth of theoretical knowledge and practical experiences. I want to invite you to give me some comments about my study. All the information you have filled in will only be used for this study and will not for any other purpose. This content does not need to be signed, and all the information you have filled in will be confidential. Therefore, please rest assured and fill in the details.

Thank you for your assistance and cooperation.

Universiti Putra Malaysia

Supervisor committee: Prof. Dr. Soh Kim Geok
Dr. Samsudin Shamsulariffin

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Expert Name: ______________________ Discipline: ___________________

Degree: ____________________________ Work Unit: __________________

1 Study Overview

1.1 Brief Summary

While prior research indicates the efficacy of High-Intensity Functional Training (HIFT) in improving physical fitness and skill performance across various sports (Feito, Brown, et al., 2019; Feito, Heinrich, et al., 2018c; Haddock et al., 2016; Poston et al., 2016), its effects on Wushu routine athletes still need to be determined. This study aims to explore the impact of high-intensity functional training on the physical fitness and jumping difficulty of Wushu routine athletes, providing valuable insights for coaches and athletes to optimize training plans. Coaches or sports researchers can use this knowledge to manage the training load of athletes better, thereby helping Wushu athletes achieve better results in Wushu jumping difficulty movements training.

1.2 Detailed Description

In this study, the intervention design part of the researchers referred to Greg Glassman's (2010) "CrossFit training guide" and designed a high-intensity functional training program based on the characteristics of wushu routines (Glassman, 2010). This study employs a Cluster Randomized Controlled Trial (CRCT) design. The experimental period of this study is 12 weeks, three times per week. The training lasts 1.5 hours, including one hour of physical fitness training and half an hour of specialized technical training. The sample for this study is male Wushu routine athletes from the Hebei Institute of Physical Education and Hebei Normal University, with 60 participants. Athletes were randomly assigned to two different training locations and divided into experimental and control groups. The specialized skills training content of the two groups is the same, with the only difference being the physical training part. The experimental group received high-intensity functional training, while the control group maintained routine training. In addition, the specific content of routine training for the control group is the school's standard training plan. The dependent variables to be measured in this study are physical fitness (strength, power, speed, endurance, and flexibility) and jumping difficulty movements (Flying Kick, Whirlwind Kick, Outward Leg Swing in Flight, and Side Somersault). This study measured the dependent variable three times throughout the intervention: baseline before the experimental intervention, post-test 1 after 6 weeks, and post-test 2 after 12 weeks. Finally, statistical analysis was conducted on the three test results.

2 Protocol Design

In this study, the intervention design part of the researchers referred to Greg Glassman's (2010) "CrossFit training guide" and designed a high-intensity functional training program based on the Competition Regulations for Wushu Routine Events at the 14th China Sports Meeting and Competition Rules of Wushu Routines, 2012.

3 Questionnaire Information

The questionnaire adopts a 4-point ordinal scale to evaluate intervention, with 1- 4 representing increasing support (1=not relevant, 2=somewhat relevant, 3=quite relevant, 4=highly relevant). Please score the HIFT training intervention. If there are other content, you can add them and indicate the name. After reading the questionnaire, please rate the following aspects and tick "√"on the corresponding rating scale.

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Table 1 : Expert Evaluation Form

Type	Relevance				Clarity				Improvement suggestions
	4	3	2	1	4	3	2	1	
Overall evaluation of the program									
Duration									
Frequency									
Intensity									
Time									
Content of Warm- up									
Content of Physical training									
Content of Cool down									
Sets and reps									
Rest time									

Table 2 : Outcome Measurement Information

TEST NAME	Outcome Measure	Measure Method	Instrument	Unit	Suggestions
Strength	Push-ups	Record the number of push-ups in 1 min.	Stopwatch	Numbers	
Power	Standing long jump	Measure the distance of the standing long jump with a measuring tape.	Measuring tape	Centimetres (cm)	
Endurance	Jumping rope	Recorded the number of jumping ropes in 1 min.	Stopwatch	Numbers	
Speed	Sprint 30 m	Use a stopwatch to record the duration of the participants' 30 m sprint.	Stopwatch	Seconds	
Flexibility	Sit-and-reach	Use the sit-and-reach box. The score is recorded as the point where their fingertips reach the measurement scale.	Sit and reach test tool	Centimetres	
Flying Kick	3 Experts	Record Flying Kick using a high-speed camera and scoring it by experts.	M120 high-speed camera	Scores	
Whirlwind Kick	3 Experts	Record Whirlwind Kick using a high-speed camera and scoring it by experts.	M120 high-speed camera	Scores	
Outward Leg Swing in Flight	3 Experts	Record Outward Leg Swing in Flight using a high-speed camera and scoring it by experts.	M120 high-speed camera	Scores	
Side Somersault	3 Experts	Record Side Somersault using a high-speed camera and scoring it by experts.	M120 high-speed camera	Scores	

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4 Questionnaire Information

This questionnaire adopts a 5-point Likert scale, with 1-5 representing increasing support (1=strongly disagree; 2=disagree; 3=not necessarily; 4=agree; 5=strongly agree). Please score the intervention program. If there is other content, you can add them and indicate the name. After reading the questionnaire, please rate the following aspects and tick "√" on the corresponding rating scale.

Table 3 : Expert Evaluation Form for Outcome Measurement

Type	Measurement Method	Relevance				Clarity				Improvement suggestions
		4	3	2	1	4	3	2	1	
Strength	Push-ups									
Power	Standing long jump									
Endurance	Jumping rope									
Speed	Sprint 30 m									
Flexibility	Sit-and-reach									
Jumping difficulty movements	Flying Kick									
	Whirlwind Kick									
	Outward Leg Swing in Flight									
	Side Somersault									

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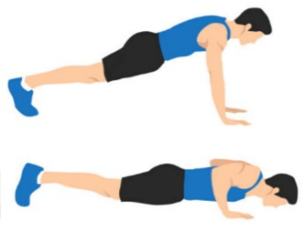
Appendix F

Variables Test Detail

1 Physical Fitness Tests

1.1 Strength Testing:



Push-ups: Record the number of push-ups in 1 min.
The participants lay face down on the floor with their hands under their shoulders. Keep the legs and body straight, and lower the elbow joint by bending it 90 degrees through continuous movement of the torso. Press down on the floor until the arms are fully extended (O. A. Yu, 2021).

1.2 Power Testing:

Standing long jump: Measure the distance of the standing long jump with a measuring tape.
Participants stand slightly apart in front of the jump line, bend their knees, and move their arms backwards, then swing their arms and jump as far as possible; Stand on both feet while maintaining an upright position; Conduct two tests. Record the best score from two tests with an accuracy of 1 centimetre (Ambrozy et al., 2022).

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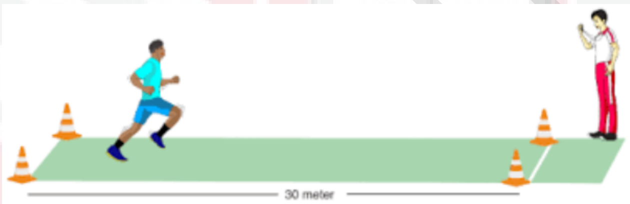
1.3 Endurance Testing:

Jumping rope: Recorded the number of jumping ropes in 1 min.
Participants rotate the rope with their arms, while their legs bounce repeatedly, maintaining vertical take-off and landing until the exercise is over (Trecroci et al., 2015).

1.4 Speed Testing:



30m sprint: Use a stopwatch to record the duration of the participants' 30 m sprint. Set cones at 0 and 30 meters along a straight line. Participants place their toes on the starting line or behind the starting line, start from a stationary position, and sprint at maximum speed over the cone at a distance of 30 meters before safely slowing down (Meyers et al., 2015).

1.5 Flexibility Testing:

Sit-and-reach: Use the sit-and-reach box. The score is recorded as the point where their fingertips reach the measurement scale.
In the sitting position of the test, participants have their legs straight, their feet pressed against the sit and read box, and their arms extended forward as much as possible to push the sliding ruler on the surface of the box (Ambrozy et al., 2022).

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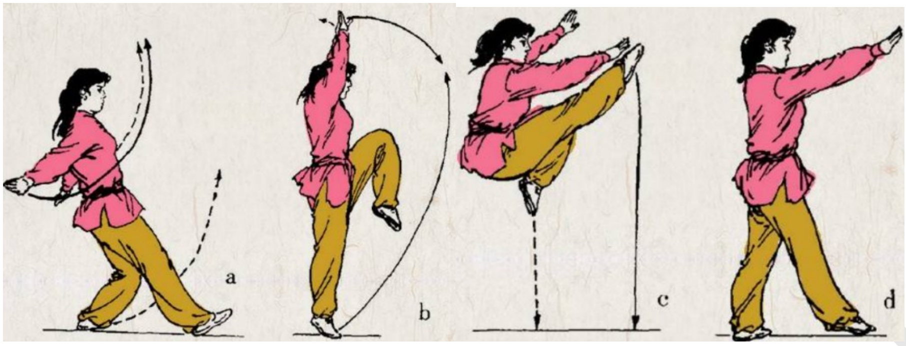
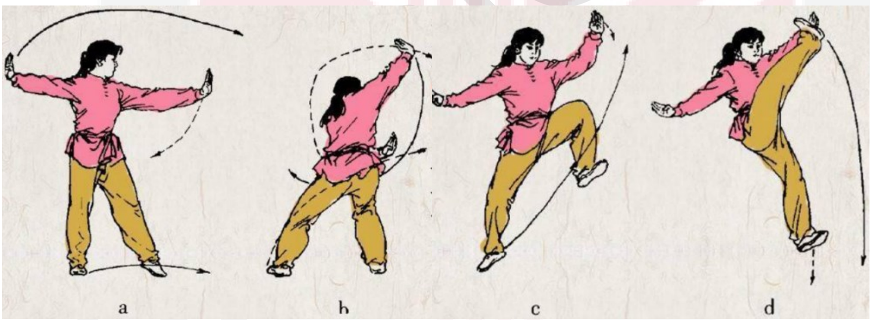
2 Jumping Difficulty Movements Tests

2.1 Flying Kick Testing:



Flying Kick testing: Record Flying Kick using a high-speed camera and scoring it by experts.
After run-up, the participants bend their left leg and raise it, quickly push their right leg to the ground and jump, take off the air, straighten their upper swing, flatten their feet, and raise their feet above their shoulders. They hit the palm of their left palm with the back of their right hand in front of their forehead, and then hit the right foot with their right hand. The right foot and left foot land one after the other (Su, 2015).

2.2 Whirlwind Kick Testing:



Whirlwind Kick testing: Record Whirlwind Kick using a high-speed camera and scoring it by experts(Su, 2015).
Participants swing their legs straight, take off with their legs straight, spin 270 degrees into the air, tap the soles of their feet with their opposite hands, feet above their shoulders, tap loudly, and spin 360 degrees to land (Su, 2015).

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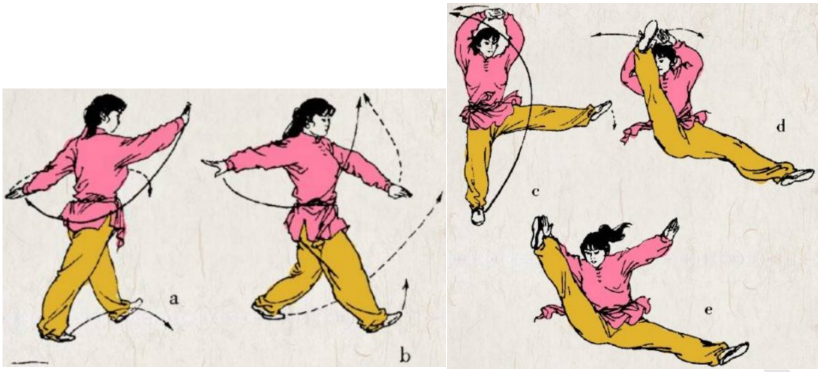
2.3 Outward Leg Swing in Flight Testing:



Outward Leg Swing in Flight: Record Outward Leg Swing in Flight using a high-speed camera and scoring it by experts.
Participants should swing their legs high, extend their take-off legs straight and swing them outward, with their feet flat and above their shoulders. They should tap their feet with both hands in sequence to form three sounds, with no one sound falling in the air (Su, 2015).

2.4 Side Somersault Testing:

Side Somersault testing: Record Side Somersault using a high-speed camera and scoring it by experts.
After run-up, the participants use their head as the rotation point, while their left leg kicks on the ground, their right leg rotates rapidly. When the right leg turns perpendicular to the ground, the left leg swings rapidly under the drive of the waist, completing a Side Somersault. Participants need to soar high, flip quickly, have straight legs, and land lightly (Su, 2015).

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Appendix G

Data Collection Forms

Form 1: Physical Fitness Data Collection Form

Basic information of male Wushu routine players:

Name: Age: Training years:

Height (cm): Weight (kg):

Test Content:

Variable	Components	Measurement	Score
Physical fitness	Strength	Push-ups	
	Power	Standing long jump	
	Endurance	Jumping rope	
	Speed	30m sprint	
	Flexibility	Sit-and-reach	

Form 2: Jumping Difficulty Movements Data Collection Form

Basic information of male Wushu routine players:

Name: Age: Training years:

Height (cm): Weight (kg):

Test Content:

Variable	Measurement	Score
Jumping Difficulty Movements	Flying Kick	
	Whirlwind Kick	
	Outward Leg Swing in Flight	
	Side Somersault	

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Appendix H

Table 1 : Levene's Test for Equality of Error Variances at Baseline (Basic Information)

Variables	**Levene Statistic**	df 1	df 2	p-value
Age (Year)	0.055	1	58	0.815
Height (Cm)	0.084	1	58	0.773
Weight (Kg)	0.462	1	58	0.499
Training background (Month)	0.137	1	58	0.712

Table 2 : Levene's Test for Equality of Error Variances at Pretest (Physical Fitness)

Variables	**Levene Statistic**	df 1	df 2	p-value
Push-ups	0.103	1	58	0.750
Standing long jump	1.056	1	58	0.308
Jumping rope	0.508	1	58	0.479
Sprint 30 m	0.024	1	58	0.877
Sit-and-reach	0.449	1	58	0.505

Table 3 : Levene's Test for Equality of Error Variances at Pretest (Jumping Difficulty Movements)

Variables	**Levene Statistic**	df 1	df 2	p-value
Flying Kick	3.170	1	58	0.080
Whirlwind Kick	1.220	1	58	0.274
Outward Leg Swing in Flight	0.707	1	58	0.404
Side Somersault	2.194	1	58	0.144

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Appendix I

Table 1 : Normality Test for Basic Information Variables at Baseline, Post-test 1, and Post-test 2

Variables	Group	Shapiro-Wilk		
		Statistic	df	p-value
Age (Year)	EG	0.877	30	0.002
	CG	0.881	30	0.003
Height (Cm)	EG	0.942	30	0.104
	CG	0.944	30	0.120
Weight (Kg)	EG	0.931	30	0.053
	CG	0.938	30	0.083
Training background (Month)	EG	0.948	30	0.150
	CG	0.964	30	0.380

Table 2 : Normality Test for Physical Fitness Variables at Baseline

Variables	Group	Shapiro-Wilk		
		Statistic	df	p-value
Push-ups	EG	0.966	30	0.448
	CG	0.964	30	0.386
Standing long jump	EG	0.938	30	0.080
	CG	0.955	30	0.233
Jumping rope	EG	0.959	30	0.301
	CG	0.948	30	0.151
Sprint 30 m	EG	0.826	30	< 0.001
	CG	0.814	30	< 0.001
Sit-and-reach	EG	0.933	30	0.061
	CG	0.932	30	0.057

Table 3 : Normality Test for Jumping Difficulty Movements Variables at Baseline

Variables	Group	Shapiro-Wilk		
		Statistic	df	p-value
Flying Kick	EG	0.956	30	0.243
	CG	0.976	30	0.699
Whirlwind Kick	EG	0.950	30	0.169
	CG	0.931	30	0.051
Outward Leg Swing in Flight	EG	0.949	30	0.160
	CG	0.934	30	0.064
Side Somersault	EG	0.950	30	0.164
	CG	0.944	30	0.117

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Appendix J

Table 1: Test-Retest Reliability of Instruments

Variable	Measurement Method	Intra-class Correlation Coefficient	95% Confidence Interval	
			Lower Bound	Upper Bound
Strength	Push-ups	0.973	0.932	0.989
Power	Standing long jump	0.982	0.956	0.993
Endurance	Jumping rope	0.846	0.652	0.936
Speed	Sprint 30 m	0.936	0.846	0.974
Flexibility	Sit-and-reach	0.959	0.900	0.954
Jumping difficulty movements	Flying Kick	0.958	0.897	0.983
	Whirlwind Kick	0.952	0.883	0.981
	Outward Leg Swing in Flight	0.942	0.860	0.977
	Side Somersault	0.938	0.852	0.987

Noted: ICC values < 0.5 indicate poor reliability, 0.5-0.75 indicate moderate reliability, 0.79-0.9 indicate good reliability, ≥ 0.90 indicate excellent reliability

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Appendix K

The PRISMA Table, Keywords and Characteristics of the Studies Examined

Figure 1 : Flow Chart of PRISMA Article Screening (Title: Effects of functional training on muscle strength, jumping, and functional movement screen in wushu athletes: A systematic review)

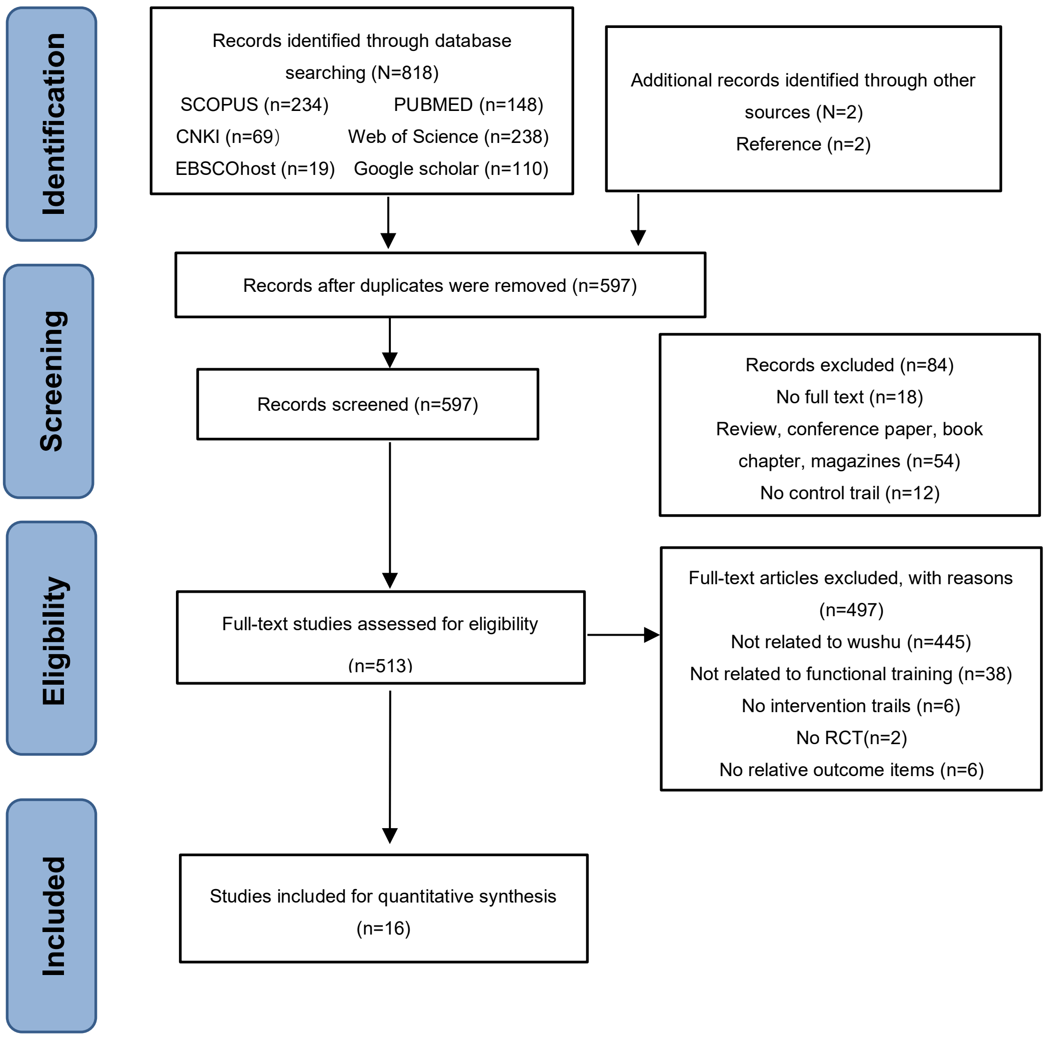

Figure 2 : Flow Chart of PRISMA Article Screening (Title: Effects of high-intensity functional training on physical fitness and sport-specific performance among the athletes: A systematic review with meta-analysis)

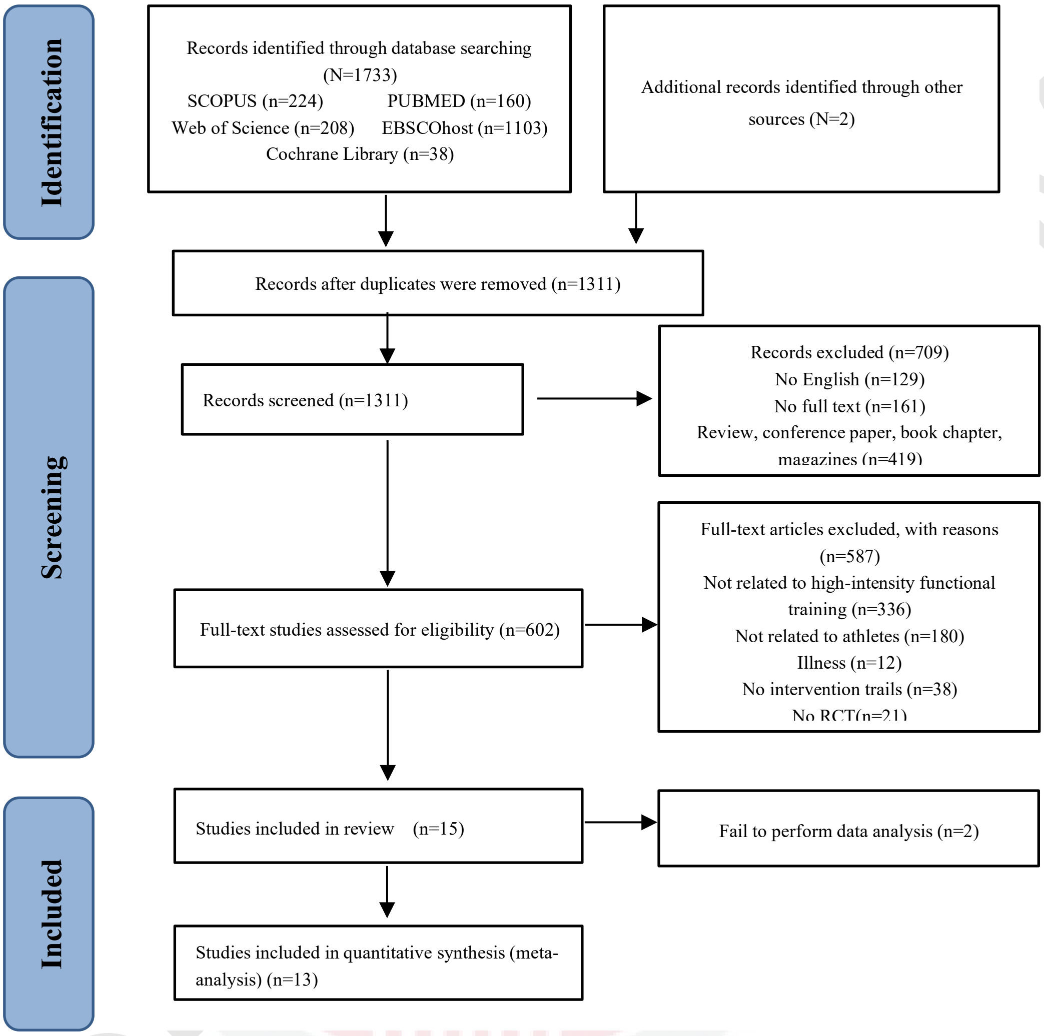

Table 1 : Predefined Combination of Keywords

Title	Keywords	Database
Effects of functional training on muscle strength, jumping, and functional movement screen in wushu athletes: A systematic review	The key words are ("high-intensity functional training" OR "functional training" OR "functional training exercises" OR "HIFT" OR "functional exercises" OR "cross fit" OR "functional balance training" OR "muscle strength" OR "jumping" OR "jumping performance" OR "functional strength training" OR "functional movement screen" OR "functional movement pattern" OR "functional movement skills" OR "FMS") AND ("wushu" OR "martial arts" OR "wushu routine" OR "traditional wushu routine" OR "competitive wushu routine" OR "wushu exercise" OR "wushu sports" OR "wushu movement" OR "wushu athlete")	WOS PubMed Scopus EBSCOhost CNKI
Effects of high-intensity functional training on physical fitness and sport-specific performance among the athletes: A systematic review with meta-analysis	("high intensity functional training" OR "high intensity functional exercise" OR "high intensity functional workout" OR "high intensity power training" OR "CrossFit" OR "Extreme conditioning program") AND (Athletes OR “Professional Athletes” OR “Elite Athletes” OR “College Athletes” OR "players") AND (“physical fitness” OR “fitness, physical” OR “physical” OR “health” OR “fitness” OR “physical endurance” OR “cardiorespiratory fitness” OR “physical conditioning” OR “body composition” OR “aerobic endurance” OR “endurance” OR “strength” OR “speed” OR “power” OR “agility” OR “balance” OR “coordination” OR “flexibility” OR “reaction time”)	WOS PubMed Scopus EBSCOhost

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Figure 3 : Summary of the Studies' Characteristics Included in This Review (Title: Effects of functional training on muscle strength, jumping, and functional movement screen in wushu athletes: A systematic review).

Study	Design	Participants characteristics	Frequency/Session duration (Mins)/Training duration	Comparator	Outcomes
Cai Z. (2020)	pre-post test	EG (n = 10), CG (n = 10) Gender: 13 M, 7F Age: 16–19 years; height: 153–175 cm; body mass: 46–78 kg Professional athletes	Freq.: 5 times/week, time: 30min, length: 8weeks	EG: Daily Wushu Routine Training and Functional Movement Correction Training Program CG: Daily Wushu Routine Training	FMS↑
Chen C. (2020)	pre-post test	EG (n = 30), CG (n = 30) Gender: 30 M, 30F Age: 1 EG: 43 ± 0.78 years; height: 140.28 ± 3.72 cm; body mass: 33.31 ± 2.27 kg Junior athletes	Freq.: 3 times/week, time: 60 min, length: 12weeks	EG: Functional Agility Training Program CG: Traditional Agility Training Program	Jump scores (HJT)↑
Fan W. (2020)	pre-post test	EG (n = 20), CG (n = 20) Gender: 20 M, 20F Age: 15.8±EG: 2 years; height: 174.6 ± 9.63 cm; body mass: 63.3 ± 10.3 kg College athletes	Freq.: 3 times/week, time: 45min, length: 8weeks	EG: Daily 24-style Taijiquan Training and Functional Training Program CG: Daily 24-style Taijiquan Training	FMS↑, Jump scores (SLJ)↑
Fang C. (2018)	pre-post test	EG (n = 10), CG (n = 10) Gender: 20F Age: 19.50 ± 2.27 years; height: 168.00 ± 5.58 cm; body mass: 62.30 ± 8.41 kg; BMI: 20.15–23.93 kg/m² Elite athletes	Freq.: 3 times/week, time: 30min, length: 8weeks	EG: Functional Movement Correction Training Program CG: Regular Training Program	FMS↑
Liu H. (2018)	pre-post test	EG (n = 6), CG (n = 6) Gender: 12 M Age: 19.00±EG: 41 years; height: 174.57 ± 5.13 cm; body mass: 74.92±1 EG: 94 kg Professional athletes	Freq.: 2 times/week, time: 20min, length: 12weeks	EG: Functional Training Program CG: Traditional Training Program	Muscle Strength (1MSU, 1MSKAR, TSB)↑
Liu X. (2018)	pre-post test	EG (n = 20), CG (n = 20) Gender: 40 M Age: 2 EG: 30 ± 0.733 years; height: 177.85 ± 3.950 cm; body mass: 7 EG: 325 ± 5.768 kg College athletes	Freq.: 2 times/week, time: 20min, length: 12weeks	EG: Body Function Movement Preparation Training Program CG: Traditional Preparation Activity Program	Muscle Strength (1 MSU) ↑, FMS↑
Song Y. (2015)	pre-post test	EG (n = 9), CG (n = 9) Gender: 10 M, 8F Age: 2 EG: 5±EG: 14 years; height: 172±EG: 87 cm; body mass: 72.4 ± 19.81 kg Professional athletes	Freq.: 3 times/week, time: 55min, length: 12weeks	EG: Functional Training Program CG: Traditional Training Program	Jump scores (VJTH, SLJ, STJ, JDAC) ↑
Sun T. (2018)	pre-post test	EG (n = 12), CG (n = 12) Gender: 24 M Age: 9.50±EG: 31 years; height: 139.75 ± 5.39 cm; body mass: 3 EG: 25 ± 4.40 kg Junior athletes	Freq.: 3 times/week, time: 45 min, length: 12weeks	EG: Functional Training Program CG: Traditional Training Program	Muscle Strength (RUOLHJ, FPJTH) ↑, FMS↑Jump scores (FF, OLSF360°, WWK360°, SS) ↑
Sun Y. (2021)	pre-post test	EG (n = 4), CG (n = 4) Gender: 4 M, 4F Age: 17. 9±EG: 40 years; height: 163. 86 ± 5.2 cm; body mass: 59.00 ± 2.16 kg; BMI: 17.2-2 EG: 4 kg/m² Professional athletes	Freq.: 3 times/week, time: 60min, length: 10weeks	EG: Functional Movement Correction Training Program CG: Traditional Physical Training Program	FMS↑, Muscle Strength (1RM Squat↑ BP↔)
Wang J. (2019)	pre-post test	EG (n = 20), CG (n = 20) Gender: 24 M, 16F Age: 13–24 years; height: 157–178 cm; body mass: 49–74 kg; BMI: 19.6–26.0 kg/m² Professional athletes	Freq.: 2 times/week, length: 12weeks	EG: Daily Wushu technical and tactical training and functional movement correction training program CG: Daily Wushu Technical and Tactical Training	FMS↑
You K. (2020)	pre-post test	EG (n = 24), CG (n = 10) Gender: 21 M, 13F Age: 19.7 ± 4.4 years; height: 17 EG: 2 ± 4.4 cm; body mass: 63.1 ± 7.0 kg Professional athletes	Freq.: 3 times/week, time: 60min, length: 12weeks	EG: Daily Wushu Routine Training and Functional Movement Correction Training Program CG: Daily Wushu Routine Training	FMS↑
Zhang C. (2022)	pre-post test	EG (n = 10), CG (n = 10) Gender: 10 M, 10F College athletes	Freq.: 2 times/week, time: 45 min, length: 12weeks	EG: Functional Training Program CG: Traditional Training Program	FMS↑
Zhang D. (2021)	pre-post test	EG (n = 12), CG (n = 12) Gender: 24 M Age: 24.42 years; height: 169.42 cm; body mass: 6 EG: 83 kg Professional athlete	Freq.: 3 times/week, time: 60min, length: 16weeks	EG: Functional Training Program CG: Traditional Strength Training Program	Muscle Strength (Power Clean↑, Burpees↑, BLT↔, PU↔)
Zhang J. (2021)	pre-post test	EG (n = 7), CG (n = 7) Gender: 14 M Age: 20.57 ± 0.78 years; height: 175.91 ± 4.86 cm; body mass: 69.51 ± 7.02 kg Professional athletes	Freq.: 3 times/week, time: 45min, length: 12weeks	EG: Functional Training Program CG: Traditional Agility Training Program	Muscle strength (EMG tester) ↑
Zhou K. (2018)	pre-post test	EG (n = 20), CG (n = 20) Gender: NR Age: 2 EG: 90 ± 0.86 years; height: 165.4 ± 2.22 cm; body mass: 65.20 ± 3.08 kg Professional athletes	EG: Freq.: 5 times/week, time: 90min, length: 4weeks 2.Freq.: 3 times/week, time: 90min, length: 6weeks	EG: Functional Movement Correction Training Program and Injury prevention training CG: Injury prevention training Program	FMS↑
Zhu H. (2017)	pre-post test	EG (n = 30), CG (n = 30) Gender: 40 M, 20F Age: 19.40 ± 0.46 years; height: 170.70 ± 15.39 cm; body mass: 60.7 ± 16.60 kg College athletes	Freq.: 1 times/week, time: 90min, length: 16weeks	EG: Functional Training Program and Wushu Special Quality Training CG: Wushu Special Quality Training	FMS↑

M, male; F, female; NR, no record; EG, experiment group; CG, control group; Freq, frequency; FMS, functional movement screening; HJT, hexagonal jump test; SLJ, standing long jump; 1 MSU, 1 min sit-ups; 1MSKAR, 1min simultaneous knee and abdominal raise; TSB, throwing solid ball practice; VJTH, vertical jump touch high; STJ, standing triple jump; RUOLHJ, Run-up one-leg high jump; FPJTH, former place jump to touch height; OLSF360°, Outward Leg Swing in Flight at 360°; WWK360°, Whirl Wind Kick at 360°; FF, Flying feet; SS, Side somersault; JDAC, jumping difficulty action cohesion; 1RM, one-repetition maximum; PU, push up; BP, bench press; BLT, Badminton Long Throw; EMG, electromyography.

Figure 4 : Summary of the Studies' Characteristics Included in This Review (Title: Effects of high-intensity functional training on physical fitness and sport-specific performance among the athletes: A systematic review with meta-analysis)

Study	Participant	Sex	Age	Exercise level	Intervention characteristics			Outcomes
					Type	Frequency	Length	
Mischenko et al. (2021) [64]	20	F	16–17 years	Professional WTF taekwondo athletes	EG: CrossFit, Rope-skipping, Tai-bo, Ki-bo, and Fightball Training CG: Routine Training	3 times/ week	9 months	SS↑ Running 100 m↑ PU↑ 1 min RS↑ SLJ↑ Attack speed↑
Osipov et al. (2019) [67]	31	M	16–17 years	Elite judo athletes	EG: CrossFit Training CG: Circular Training	3 times/ week	10 months	Competition score↑
Yüksel et al. (2019) [70]	32	M	21.72 ±1.40 years	Amateur wrestlers	EG: CrossFit Training CG: Classical Wrestling Training	3 times/ week,	8 weeks	Bench press↑ Squat jump↑
Ambroży et al. (2022) [59]	60	M	20.07 ± 1.46 years	Professional kickboxers	EG: CrossFit Training CG: Conventional Kickboxing Training	3 times/ week	8 weeks	Dynamic sit-ups↑ SLJ↑ Tapping↑ Cooper test↑ SR↑ Shuttle run 10x5 m↑ Movement speed↑
Kudryavtsev et al. (2023) [63]	44	M	21.06±3.42 years	Elite sambo athletes	EG: CrossFit Training CG: Strength Training	3 times/ week	4 weeks	Rank position↑
Zhu. (2023) [69]	24	NR	19.824 ±0.469 years	Professional aerobic gymnastics athletes	EG: CrossFit training CG: Normal aerobics training	NR	9 weeks	STMB↑ SR↑ Movement performance score↑
Osipov et al. (2022) [65]	53	M	17.22±1.37 years	Elite judo athletes	EG: CrossFit Training CG: Strength Training	4 times/ week	8 weeks	Pull up↑
Galimova et al. (2018) [62]	40	NR	18–19 years	College boxer	EG: CrossFit Training CG: Traditional training	4 times/ week	12 weeks	Attack strength↑
Türker & Yüksel. (2020) [68]	32	M	20.8 ± 1.15 years	Professional wrestlers	EG1: Classic CrossFit EG2: CrossFit AMRAP	3 times/ week	8 weeks	Anaerobic power↑
Caloglu & Yuksel. (2020) [41]	40	M	21.33 ± 1.78 years	Professional wrestlers	EG: CrossFit Training CG: No additional training	3 times/ week	8weeks	Anaerobic power↑ Dynamic balance↑
Avetisyan et al. (2022) [60]	20	M	11 ± 0.64 years	Junior judo athletes	EG: CrossFit Training CG: Traditional Training	2 times/ week	5 months	Pull-up↑ SLJ↑ Shuttle run time 4 × 10 m↔ Burpees (repetitions in 30 s) ↔
Bozdoğan. (2021) [61]	22	F	16.41±1.29 years	Professional Volleyball Players	EG: HIFT CG: Routine training	2 times/ week	12 weeks	Shuttle run10 x 20 m↑ CMJ↑
Osipov et al. (2017) [66]	60	NR	20–21 years	Professional martial arts athletes	EG: CrossFit Training CG: Circular and Interval Training	2 times/ week	6 months	Competition endurance↑

M, male; F, female; NR, no record; EG, experiment group; CG, control group; HIFT = high-intensity functional training; SS, side split; PU, pull up; RS, rope skipping; SLJ, standing long jump; SR, sit and reach; STMB, side throw medicine ball; CMJ, counter movement jump. ↑, significant improvement; ↔, no significant difference.

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Appendix L

Daily Diet and Physical Activity Control Record Form

Table 1 : Daily Dietary Guidelines

Dietary Recommendations	Description
Protein Sources	Protein is crucial for muscle repair and bone health, especially during exercise interventions. Recommended protein sources include: - Lean meats (e.g., chicken breast, lean beef, pork) - Fish (e.g., salmon, cod, tuna, other omega-3 fatty acid-rich fish) - Eggs (e.g., whole eggs or egg whites) - Beans (e.g., soybeans, black beans, mung beans) - Low-fat dairy products (e.g., low-fat milk, yogurt, cheese) - Plant-based protein (e.g., tofu, soy milk)
Vegetables and Fruits	Vegetables and fruits are rich in antioxidants, vitamin C, E, calcium, etc., which help reduce inflammation and improve immune and bone health. - Leafy vegetables (e.g., spinach, kale, collard greens, rich in calcium and magnesium) - Vitamin C-rich fruits (e.g., oranges, lemons, strawberries, kiwis) - Potassium and vitamin A-rich vegetables/fruits (e.g., carrots, pumpkins, tomatoes, bell peppers) - Berry fruits (e.g., blueberries, blackberries, raspberries, rich in antioxidants)
Whole Grains and Complex Carbs	Choose whole grains and complex carbohydrates to stabilize blood sugar levels and support energy needs: - Whole wheat bread, brown rice, oats, quinoa - Sweet potatoes, yams - Whole wheat noodles or pasta
Healthy Fats	Healthy fats are essential for bone, joint, and nervous system function. - Olive oil, flaxseed oil, fish oil - Nuts and seeds (e.g., almonds, walnuts, chia seeds, sunflower seeds) - Avocado

	- Deep-sea fish (e.g., salmon, tuna, omega-3 fatty acid-rich fish)
Calcium and Vitamin D	Calcium and vitamin D are especially important for maintaining bone health. - Dairy products (e.g., milk, yogurt, cheese) - Leafy vegetables (e.g., spinach, kale, collard greens) - Vitamin D-fortified foods (e.g., fortified milk, soy milk, fish) - Sun exposure (moderate sunlight helps with vitamin D synthesis in the body)
Hydration	Adequate hydration supports normal metabolism, blood circulation, and metabolism. - Recommended daily water intake: university students should aim to drink 8 cups (about 2 liters) of water daily, especially before and after exercise to prevent dehydration.
Avoid Processed Foods	Minimize processed foods high in sugar, fat, and salt, as they not only affect health but may increase inflammation and worsen cervical discomfort. - Avoid foods high in trans fats - Reduce sugar intake, avoid sugary drinks
Meal Distribution	To maintain stable energy and avoid blood sugar fluctuations, it is recommended to consume 3 meals and 2 snacks per day, ensuring each meal includes protein, healthy fats, and carbohydrates. - Breakfast: Oats, whole wheat bread, low-fat milk, one fruit - Lunch: Chicken breast or fish, brown rice or whole wheat pasta, leafy vegetables - Dinner: Fish or tofu, sweet potatoes or quinoa, stir-fried vegetables - Snacks: A handful of nuts, yogurt, fruit and vegetable slices

Table 2 : Daily Dietary Recommendations

Meal	Time	Food Components	Suggestions
Breakfast	7:00-8:00	**Staples**: Whole wheat bread, Oatmeal **Protein**: Eggs, Low-fat yogurt **Drinks**: Milk, Soy milk	Whole wheat bread (2 slices) + Boiled egg (1) + Low-fat milk (1 cup) + Banana (1)
Lunch	12:00-13:30	**Staples**: Brown rice, Sweet potato, Millet porridge **Protein**: Chicken breast, Fish (salmon, tuna), Tofu **Vegetables**: Spinach, Tomatoes, Carrots **Drinks**: Clear soup	Brown rice + Grilled chicken breast + Stir-fried spinach + Tomato salad + Clear soup (chicken or vegetable broth)
Dinner	18:30-19:30	**Staples**: Sweet potato, Quinoa, Whole wheat noodles **Protein**: Cod fish, Tofu, Chicken breast **Vegetables**: Carrots, Bell peppers, Green leafy vegetables **Drinks**: Herbal tea	Quinoa + Steamed cod fish + Stir-fried carrots and bok choy + Chrysanthemum tea (1 cup)
Snacks	Throughout the day	**Morning Snack**: Nuts (almonds, walnuts) **Afternoon Snack**: Apple, Yogurt	A handful of nuts (almonds, walnuts) + Apple or yogurt

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Table 3 : DRIs Record Form

Form：Record participants' weekly energy intake (Kcal)

Type of Group: ________________ Assistant's Name:______________

No	Name	Gender	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
16														
17														

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Table 4 : Daily Physical Activity Record

Form：Self-Report Record Form

Name: ___________________ Assistant's Name:__________________ Week: ___________________

Contents	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Completed the daily diet plan as required							
Sleep time reached 7-9 hours							
Study time was within 9 hours							
Used electronic products for no more than 4 hours							
No additional physical activities							
No symptoms of physical fatigue							
Other abnormalities in physical health							

Notice:

1.Please record all relevant activities daily according to the experimental requirements and specific supervision content.Please mark the completed items with '√'.

2.The sleep time standard is set according to the recommendations of the American Academy of Sleep Medicine and the Sleep Research Society, which suggest that adults aged 18-60 should have 7-9 hours of sleep per night (Watson et al., 2015).

3.Study time includes both classroom learning and self-study time. The standard is based on the average weekly study time of five hours per day for students in the selected colleges, combined with previous research reports on the self-study time of Chinese college students (approximately four hours per day) (Zhu, 2016).

4. Electronic device usage time: This includes the use of mobile phones, computers, televisions, and other devices. The standard is based on recommendations from previous studies regarding the impact of smart devices on physical fitness (Al'Saani et al., 2023; Kim & Koo, 2016).

5.Other health abnormalities: Any abnormal diet, physical discomfort (such as illness, menstruation, or injury), etc., should be truthfully recorded and reported to the research assistant in a timely manner

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BIODATA OF STUDENT

Wang Xinzhi is expected to graduate with a doctoral degree in Physical Education. from the Universiti Putra Malaysia (UPM) at the Department of Sports Studies by the end of March 2025. He completed the course with excellent results during his doctoral study, and published some articles in SCl indexed journal under the guidance from Prof. Soh. He has benefited a lot throughout his doctorate career.

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LIST OF PUBLICATIONS

Journals

Wang et al., (2024). Effects of functional training on muscle strength, jumping, and functional movement screen in wushu athletes: A systematic review. Heliyon, 10(2), e24087.

Wang et al., (2023). Effects of high-intensity functional training on physical fitness and sport-specific performance among the athletes: A systematic review with meta-analysis. PLOS ONE, 18(12), e0295531.

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Wang et al., (2025). Effects of high-intensity functional training on physical fitness in healthy individuals: A systematic review with meta-analysis. BMC Public Health, 25(1), 528.

Conferences Attended during PhD Studies

The 9th ASEAN Council of Physical Education and Sports (ACPES) International Conference 2023

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